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BUREAU OF PLANT INDUSTRY—BULLETIN No. 49.

B. T. GALLOWAY, Chief of Bureau.

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THE CULTURE OF THE CENTRAL AMERICAN RUBBER TREE.

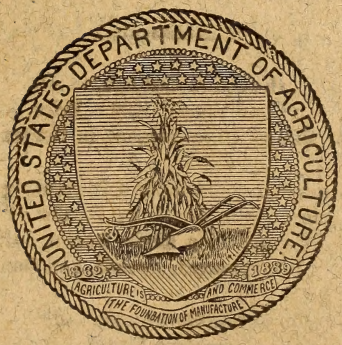
BY

O. F. COOK,

BOTANIST IN CHARGE OF INVESTIGATIONS IN TROPICAL AGRICULTURE.

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

ISSUED OCTOBER 1, 1903.



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BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

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[Continued on page 3 of cover.]

PLANTED CASTILLA TREES ABOUT 14 YEARS OLD.

U. S. DEPARTMENT OF AGRICULTURE.
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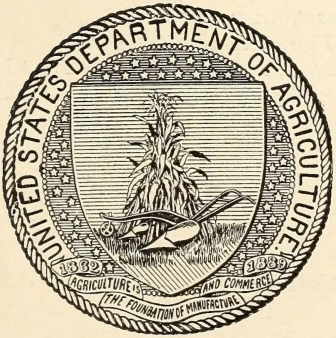

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

BUREAU OF PLANT INDUSTRY.

B. T. Galloway, *Chief of Bureau.*

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

SCIENTIFIC STAFF.

Frederick V. Coville, *Botanist.*

O. F. Cook, *Botanist in Charge of Investigations in Tropical Agriculture.*
Rodney H. True, *Physiologist, Drug and Medicinal Plant Investigations.*
Lyster H. Dewey, *Botanist in Charge of Investigations of Fiber Plants.*
V. K. Chesnut, *Assistant Botanist in Charge of Investigations of Poisonous Plants.*
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G. N. Collins, *Assistant Botanist, Tropical Agriculture.*
William E. Safford, *Assistant Curator, Tropical Agriculture.*
F. H. Hillman, *Assistant Botanist, Seed Herbarium.*
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 7, 1903.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 49 of the series of this Bureau, the accompanying paper entitled "The Culture of the Central American Rubber Tree." It is especially opportune at this time that correct information should be disseminated on this subject, as interested parties have spread many delusive reports with a view to encouraging enterprises designed to exploit the rubber industry. Under these circumstances accurate and reliable information should be accessible to all classes of our citizens. This paper was prepared by Mr. O. F. Cook, Botanist in Charge of Investigations in Tropical Agriculture, and has been submitted by the Botanist with a view to publication.

The eighteen half-tone illustrations are considered necessary to a complete understanding of the text of this Bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In the year 1902 the United States imported coffee to the value of $70,982,155, sugar[a] $55,061,097, and crude rubber $24,899,230. The imports of crude rubber for the last five years were valued as follows:

1898	$25,386,010
1899	31,707,630
1900	31,376,867
1901	28,455,383
1902	24,899,230
Total	141,825,120
Average	28,365,024

After sugar and coffee, crude rubber is the largest of the tropical imports of the United States, and it is the only one of these three for which we are still entirely dependent on foreign countries. Rubber culture is also the tropical industry in which the largest foreign investment of American capital has been made, and this is far larger than that of any other country.

The present paper on "The Culture of the Central American Rubber Tree" is the result of a preliminary study of rubber culture in Guatemala and Southern Mexico by Mr. O. F. Cook, Botanist in Charge of Investigations in Tropical Agriculture, who has already left for a second visit to Central America and Mexico, during which further attention will be devoted to the same subject.

These studies are directed primarily to the question whether rubber culture is promising for Porto Rico and the Philippines, and the principal fact established in this report, that a continuously humid climate is neither essential nor even desirable for rubber culture, promises well for the extension of this industry to the tropical islands of the United States. As a basis of effort in this direction the more important results of the experiments which have been made with the Para and other rubber trees in the East Indies and elsewhere have been brought together, with explanations of their possible bearing upon the culture of the Central American rubber tree.

The paper will have, however, a more immediate and popular interest in connection with the subject of investments in rubber culture,

[a] Not including imports from Hawaii and Porto Rico.

upon which this Department continues to receive a large amount of correspondence of a character which it has been very difficult to treat satisfactorily by letter.

A large proportion of the notes and illustrations used in the present paper were secured in the Soconusco district of Southern Mexico on the estate of the La Zacualpa Rubber Plantation Company, through whose hospitality and numerous courtesies the work of Mr. Cook was greatly facilitated.

FREDERICK V. COVILLE,
Botanist.

OFFICE OF BOTANICAL INVESTIGATIONS
AND EXPERIMENTS,
Washington, D. C., May 18, 1903.

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THE CULTURE OF THE CENTRAL AMERICAN RUBBER TREE.

INTRODUCTION.

Among the more striking results of the industrial progress of the nineteenth century was the rapid multiplication of the uses of rubber and an ever-increasing demand for the raw material. For several decades the world's needs were met by the Para district of eastern Brazil, but with steadily advancing prices as an inducement the entire Amazon Valley, and indeed all tropical regions of both hemispheres, have been ransacked in search of additional wild supplies. It is not yet true, as sometimes represented, that the natural product is exhausted or that a rubber famine is to be anticipated at an early date. Within the last decade the value of good grades of rubber passed from the neighborhood of 25 cents to a dollar and upward per pound, and the rubber-gathering industry met with an expansion sufficiently rapid to more than keep pace with the demand, so that a period of somewhat more moderate prices has ensued. But with a steady increase in the use of rubber in the arts and no very general improvement in the destructive methods of gathering the wild product, it is to be expected that this respite will be brief and that the question of the world's future supply will soon become more acute.

The preservation of the wild rubber forests is naturally receiving more and more attention in the countries in which they are so important a source of wealth, but measures of safety are least likely to be applied in the very remote and unexploited districts where they would do the most good. Rubber is still very largely a product of savage rather than of civilized industry; in fact, it is now by far the most important contribution of barbarous races to our industrial civilization. While this continues to be the fact there will be little change in the careless and wasteful methods of the past, but the appreciation of rubber forests as permanent sources of income may be expected to increase, so that the continued advance in the price of rubber no longer means merely the rapid extinction of wild rubber trees, but implies also increased interest in the protection and improvement of the more productive natural forests. Such a tendency is already manifest,

especially in Brazil and in adjacent countries of South America, and probably means that the natural supply of rubber will never entirely cease, but will gradually become the basis for the development of scientific forestry in the Tropics. There is, however, no probability that any large proportion of the present producing areas will become permanent sources of supply, and the cultural production of rubber well deserves the serious consideration it is now receiving in all agricultural regions of the Tropics.

Rubber culture is no new or recent proposition, since beginnings were made nearly three decades ago. With an annual plant twenty years of experience would teach us much, but for dealing with long-lived trees that period is very short, and it need not be a matter of surprise that rubber culture is still in the experimental stage. Many cultural mistakes are still made with plants that have been in domestication for thousands of years, and the failure of the first attempts with rubber might have been predicted simply on the grounds of probability. Nevertheless, a distinct period of discouragement resulted, the effects of which are still felt and will doubtless remain until more detailed knowledge makes plain the possibility of avoiding the obstacles previously encountered.

Progress in practical matters as well as in purely scientific subjects depends much upon theories. On the failure of the first experiments, the theory that rubber trees could be profitably cultivated was discarded by many who came to the conclusion that planted trees will not produce rubber. This view is by no means extinct, especially among those who have abandoned rubber planting in disgust. An adverse opinion of this kind is popular with some because it serves as a general explanation of failure and spares the annoying suggestion of cultural errors and oversights.

Like other members of the vegetable kingdom the performances of rubber trees have been found to depend upon the conditions under which they grow, whether planted or self sown, unless they were injured in planting. In the American Tropics and in the East Indies the possibility of the cultural production of rubber has been demonstrated. This fact is giving the pendulum the return swing in the direction of sanguine expectations, and the assurance that rubber can be produced culturally is too often taken as a verification of the original estimates of yields and profits in spite of the fact that some of these have been disavowed by their authors. A future of easy prosperity for the rubber planter is held to be assured, and the opinion that rubber culture is still experimental is resented as blindly conservative. The lesson of the former miscalculation is forgotten by the new generation of promoters, and the fact that rubber trees have been found to thrive in a given locality is taken as sufficient evidence that they will meet even the most reckless estimates of productiveness

and profits. The opening of large plantations under untried conditions in Porto Rico and the Philippines is advocated, and the investing public is assured, in effect, that the returns from rubber culture are to be so great that the exercise of ordinary agricultural skill and business caution is unnecessary, though the fact remains that a large measure of both is likely to be required if the numerous unsolved problems of the new industry are to be overcome without ruinously expensive experiments.

THE STATUS OF CASTILLA RUBBER CULTURE.

Many current discussions turn upon the question whether rubber culture is still in the experimental stage. This is the most frequent objection of those who lack confidence in rubber culture, and naturally arouses a strong protest from those who insist that rubber planting is the safest and most remunerative branch of agriculture.

It is true that rubber culture is no longer a new idea, since it was considered by the Government of British India as early as 1872, and Castilla was introduced into India in 1876. The Hon. Matías Romero, formerly minister from Mexico to the United States, also began to write on the subject of rubber culture in 1872. But the success of rubber culture can scarcely be demonstrated from the experiments of twenty or thirty years ago, since the results of few, if any, of these appeared sufficiently promising to justify their continuation. The plantation of Señor Romero was located in the Soconusco district of the State of Chiapas, in southern Mexico, and was early abandoned. The small plot of trees visited by the writer at La Zacualpa, some 60 miles northwest from Tapachula (see frontispiece), was probably planted as a result of the interest aroused by Señor Romero in this vicinity. The trees at La Zacualpa were set, however, as shade for cacao, and not as an independent culture. This was not the only experiment with rubber planting in the same region, but it seems to have been the only one which resulted favorably enough to call for the further investment of capital in the commercial production of rubber.

There have been, and still are, three general opinions regarding rubber culture. The first is that rubber can be produced at a profit wherever the trees will grow. The very frequent failure to secure rubber in paying quantities from planted trees gave rise to the second opinion that rubber could not be produced in cultivation. But these ideas are beginning to give place to the third and more rational view that rubber, like other agricultural crops, can be produced profitably only under favorable conditions, or, in other words, rubber culture may be said to have reached the stage when it can no longer be indiscriminately advocated nor indiscriminately condemned. If no other evidence were obtainable, the planted trees visited in Soconusco would

prove that rubber can be produced in cultivation, and the investment of millions of dollars in Castilla culture in tropical Mexico and Central America may be taken as evidence that many are convinced that such production will be profitable. It is most unfortunate, however, that so many of those who have been attracted by the recent revival of interest in the subject have accepted the first view rather than the third, and have thus needlessly jeopardized their capital by attempting to grow rubber under conditions which the older experiments have shown to be more or less unfavorable.

When it is claimed that rubber culture has passed the experimental stage this should be taken to mean that the agricultural production of rubber has been demonstrated as possible. But from the agricultural standpoint it is even more true that rubber culture has only entered the experimental stage, since very little is known regarding conditions, methods, and results.

CASTILLA VERSUS HEVEA.

The preceding paragraphs may serve to explain why no decision has been reached on the very important question of the relative agricultural value of the different rubber-producing trees. It has been supposed thus far that the climatic and cultural requirements of the Para rubber tree (Hevea) and the Central American rubber tree (Castilla) were quite different, but the results of the present study seem to indicate that the differences, if any, have been much overestimated. The comparative experiments thus far carried on in botanical gardens have, at most, but a local value, and can not be accepted as final. In Java, for example, both Castilla and Hevea were condemned in favor of *Ficus elastica* (Assam rubber), but it now seems probable that the continuously humid mountainous district in which the experiment was tried was quite unsuited for testing the productive powers of Castilla, and probably of Hevea also.

It may be that no one rubber-producing species will attain any great or exclusive preponderance, but that different climatic and soil conditions can best be met by planting different trees. The wisest policy in untried regions will be to make experimental plantings of all of the more promising rubber trees. At present these are three in number: Castilla, Hevea, and Ficus. Manihot (ceara rubber) can probably be omitted from the list except for regions too dry for the others.

UNCERTAINTIES ATTENDING RUBBER CULTURE.

Some few rubber planters have not been contented to plant anywhere that the rubber trees could be made to grow, or even where they grew wild, but have emulated the northern farmers who planted young sugar maples close by the productive parent trees. Some of

the plantations of Mexico seem to be outside the natural range of Castilla, as they have found it necessary to import the seeds from other districts. Others are in localities where the rubber tree grows wild but produces little or no rubber. For example, in Soconusco it would be entirely possible to establish a rubber plantation on the lower slopes of the mountainous and humid coffee district, where wild Castilla is not uncommon. Fortunately, however, rubber planting has been confined to the warmer and drier coast plain and to localities where both wild and planted trees have been found productive. That it will become possible by correct methods to produce rubber in countries where the tree is not native, and even in localities where the wild trees do not yield well, is to be expected, but it can scarcely be repeated too often that the planting of more than experimental quantities under untried conditions is a hazardous enterprise, to say the least, and not to be indulged in except by those who can afford to lose.

In the British dependencies of the Malay peninsula, Para rubber for several years past has enjoyed an era of rapidly increasing popularity, heightened recently by the fact that some of the earlier plantings have begun to produce and that good prices have been obtained for the samples shipped to Europe. But even yet the prize of success may escape, since it appears that the new East Indian Para rubber, though received with high approval by the importers, has been found seriously defective in quality.

We have already expressed our opinion of samples of the cultivated rubber from the Malay states, which, while attractive in appearance, do not really resemble the fine Para rubber now in use. It is much softer than the Brazilian product, and of much shorter "fiber." It could not be used, for example, in thread, elastic bands, or any fine, pure gum goods. In solution, it quickly loses its tenacity, so that it would not do for high-grade cements. And it readily softens with age. Perhaps some of these defects might be removed by the introduction in the East of the methods of coagulation employed in the Amazon rubber camps, but we are disposed to believe that the Eastern planters have really produced a new grade of rubber, and that the Para article can never wholly be duplicated by them. It is to be understood, of course, that the rubber is valuable, and will find a ready market at a price which is likely to yield a profit, but such samples as have reached us, valued from the manufacturer's standpoints, would rank at least 25 per cent lower than fine Para.

The good prices realized in London, doubtless, have been due to the cleanly appearance of the new rubber. And they have been based on the judgment of brokers, rather than results of practical tests in the factory. * * * The manufacturer's test is the one by which the value of this rubber will be judged finally, regardless of what may be the judgment of brokers to-day. We do not mean to dampen the enthusiasm of the planters, but there is such a thing as basing their plans upon estimates of profits that are impossible.[a]

It is certainly to be hoped that this disappointing report can be traced to some accident to the samples condemned, or that the quality

[a] India Rubber World, 1902.

will improve as the trees increase in age. And yet it may not be a matter of surprise that with rubber, as with so many other natural products, perfection will be found to depend on some apparently trifling and long-overlooked peculiarity of soil or climate.

But whatever the true merits or prospects of the Para rubber industry of the East Indies, the above report well illustrates the vicissitudes of hope and failure to which new cultures must remain subject until scientific knowledge and practical experience have revealed the principal factors and shown something of their relative significance.

It is impossible to tell in advance which fact will be of directly practical importance in the development of a new and complicated subject like rubber culture. Nothing should be disregarded which tends to bring the rubber-producing species into relation with the facts which have been accumulated with regard to other plants, or which can serve as a suggestion for the solution of any of the all-too-numerous problems.

EXTENT OF THE CASTILLA RUBBER INDUSTRY.

At present the two centers of rubber culture are located in the East Indies, particularly in Ceylon and the British dependencies of the Malay Peninsula, and in Central America and southern Mexico. The India Rubber World has recently attempted a census of the rubber-planting stock companies of Mexico, and 26 of these have reported a total of 11,117 acres planted with 5,443,105 trees. The numerous companies which did not report and the many estates owned by individuals would probably bring the total area devoted to rubber to the neighborhood of 20,000 acres, or several times the space planted with Hevea in the East Indies. In the above estimate no account is taken of the numerous rubber plantations of the other Central American countries and the beginnings which have been made with Castilla in Colombia and Venezuela, which would mean an addition of several thousand acres to the estimate for Castilla.

CASTILLA IN THE WEST INDIES.

Castilla was introduced into the botanical gardens of the British West Indian colonies shortly after it was sent to British India in 1875, but rubber culture seems not to have become established in any of them, although numerous favorable reports from Trinidad and other islands have been published.

Castilla appears to produce good rubber and to do remarkably well in districts in Dominica where the average rainfall is about 70 inches a year. I am satisfied that the soil and climate of that island are suitable for the cultivation of rubber trees. * * *

We find the Central American rubber tree most useful in Jamaica, and I am recommending estate owners in some districts to plant these trees along their boundaries so that, if they are not used for anything else, they will make excellent fence

posts. I am also advising them to plant it in their woods, so that the seeds may be distributed by birds. * * *

The Tobago rubber trees are grown on the cacao estates for shade purposes. On one estate the growth made by the trees was remarkable. The Central American rubber tree is the one chiefly cultivated. [a]

Castilla seems to have been introduced into eastern Cuba several years ago. A sample of rubber apparently of excellent quality has been received recently from Mr. Henry McManus, who states that rubber trees are growing on three estates—"Nuñez," "Palmarejo," and "La Consolacion"—in the vicinity of Baracoa. The annual rainfall in those localities is about 125 inches, and Castilla is said to thrive well.

CASTILLA CULTURE FOR PORTO RICO.

Studies of Castilla in its native home in Mexico have resulted in a more favorable opinion regarding the prospects of Castilla in Porto Rico, since it is believed that the requirement of continuous heat and humidity has been overstated. The north and south sides of Porto Rico have very different climates; some districts of the north may be too wet and much of the south too dry for Castilla. There are, however, particularly toward the southwest corner of the island, many places where the climatic conditions are not unsuited for Castilla and where experimental plantings should be made. If the soil and other local conditions do not prove unfavorable it will be possible to utilize for rubber culture much waste land too low and too much exposed to drought for coffee.

RUBBER IN THE PHILIPPINES.

The United States Department of Agriculture has received from the Philippines several samples of low-grade gutta-percha but no rubber, and it has not been supposed that native rubber trees exist in the islands. It has recently been announced, however, that a shipment of native rubber has been sent from Zamboanga, island of Mindanao, to a San Francisco firm. This rubber is said to be derived from *Ficus elastica*, the Assam rubber tree of the East Indies. [b]

That the Ficus is confined to Mindanao is scarcely to be expected in view of the fact that it has been reported on Formosa, far north of Luzon. It should accordingly be sought for on other islands of the group.

The existence of what may prove to be another rubber plant is indicated by the following paragraph from a recent letter received by

[a] West Indian Bulletin, **2**:112, 1901.

[b] India Rubber World, **27**:115. The existence of the true *Ficus elastica* in the Philippines is unknown to botanists. Blanco's Flora states that an elastic gum is obtained from *Ficus rostrata*, a species later referred to *Ficus radicans* as variety *angulosa*.

this Department from Mr. Henry E. Neibert, an American teacher stationed at Jaro, on the island of Leyte:

> There is a rubber plant indigenous to the soil here, the native name of which in the Binasaya dialect is *quiliquili* (pronounced *ke-li-ke-li*). Neither the natives nor the Spaniards seem to be aware of its commercial value, and have cut all easily accessible specimens at an early age for the columns which support their houses. Because it is a prolific plant is the only reason that it still exists.

It is not known that either Castilla or Hevea has been introduced into the Philippines. Seeds for experimental planting can be secured more easily from Ceylon or the Straits Settlements than from tropical America, but, as soon as the superiority of any one or more of the Mexican or Central American varieties of Castilla has been determined, a new supply of seed should be sent out. The suitability of some of the various soils and climatic conditions found in the Philippines for the culture of Castilla is to be expected. The character of the natural vegetation would enable one conversant with the subject to select the most favorable localities for experimental plantings, but until these have given evidence of success extensive undertakings will not be justified.

BOTANICAL STUDY OF CASTILLA.

DIFFICULTIES IN STUDYING TROPICAL TREES.

On account of their larger size it might be supposed that trees would be the easiest of all objects of botanical study, but this is far from being the fact. The size itself makes it difficult to observe a tree as a whole or to bring numerous individuals under the eye at once, as may be done with smaller plants. Moreover, trees can not be preserved as complete specimens, and only small fragments can be accommodated for ready reference in the herbarium. Nevertheless, the task may be said to be comparatively simple with the trees of temperate climates, where forests are relatively open and are frequently composed of only a few kinds of trees, or perhaps a single species. In the Tropics a natural forest of one species is practically unknown; hundreds of kinds grow indiscriminately mixed together. Crowded together in tropical forests trees have nothing like the shapes or habits they would assume if standing alone. All are putting forth, as it were, their best efforts to grow tall and thus secure as much sunlight as possible. Their leaves and branches are inextricably confused, interlaced with climbing plants, and encumbered with parasites and epiphytes. To cut down a particular tree may be impossible unless one is willing to clear a large neighboring area to permit it to fall. Unless the botanist finds a clearing, his opportunities for securing even the desired fragments of branches with leaves, flowers, and fruit may be extremely few, hence our knowledge of tropical trees is still in the early pioneer stages. Very recently the rubber tree of the Para

district has been described and named as a new species distinct from the original *Hevea braziliensis*, which came from the upper Orinoco.

THE ORIGINAL DESCRIPTION OF CASTILLA.

The rubber tree of Mexico received a botanical description and name in a paper read by Cervantes before the Real Jardín Botánico (Royal Botanic Garden) of the City of Mexico, July 2, 1794, and printed with an engraved plate a month later in the Suplemento á la Gaceta de Literatura, a publication now very rare. According to Collins the British Museum copy lacks the illustration of the plant, but that of the Library of Congress at Washington is complete, and the figures are shown in photographic reproduction as Plate II of the present bulletin. An English translation of Cervantes's account of the rubber tree was published anonymously in 1805, but is said to have been the work of Charles Koenig, keeper of the mineralogical department of the British Museum. In this the name of the plant was changed from Castilla to Castilloa, an amendment which has become generally current, although justified by no recognized rule of botanical nomenclature. The tree was named Castilla in honor of Castillo, a Spanish botanist who died in 1793 while engaged in the preparation of a flora of Mexico. To modify Castilla into Castilloa was not the first change suggested, since a Mexican botanist had already proposed the word Castella in the same year in which Castilla was published. The question is, of course, of the slightest importance, and turns on whether the personal name should be latinized or not in forming from it the name of a plant. Castella and Castilloa would represent extremes of opinion, but few botanists, if any, would hold that Castilla was incorrect, and fewer still would recognize the right of anybody to change it. It will be apparent from comparison of our illustrations (see Plates IV to VII) that Cervantes's plate looks little enough like our photographs of the flowers and fruit of Castilla. Indeed, it need not be a matter of surprise if it should be found that they were taken from some different tree,[a] though there seems to be none known at present from Mexico from which they seem likely to have been made. The rounded clusters of fruits pointed with long recurved styles have considerable resemblance to those of some of the species of the South American genus Perebea, and the long, loosely-scaled staminate flower is very unlike those of the true rubber tree, though all these discrepancies may be due merely to careless drawing. That Cervantes was not personally acquainted with the rubber tree in nature seems to be indicated by his saying that the tree is "one of the tallest and most leafy which grow on the hot coasts of New Spain," and again that "the trunk is 3 or 4 yards in thickness."

[a] Further studies show that more than one species of Castilla is being cultivated in Mexico and Central America, but the detailed results can not be included in the present report.

DESCRIPTION AND BOTANICAL CHARACTERS.

General appearance.—Like its relatives, the fig, the breadfruit, and the trumpet tree, Castilla has a characteristic general appearance and habit of growth which render it very easy of recognition. The trunk, with its rather smooth light-gray bark, has no very striking peculiarity, but the slender, simple branches, with their large oval leaves pendant in two rows, are similar to those of very few other trees. These features are perhaps most conspicuous in trees two or three years old, such as that shown in Plate VIII, since the leaves are larger and the slender branches are longer than in trees of greater size.

The temporary branches of Castilla.—The apparent impossibility that a young tree should have longer branches than an old one is realized in Castilla through the curious habit of self-pruning (Pl. X). Such a tree as that shown in Plate VIII has, in fact, no true or permanent branches, which generally do not appear before the third or fourth year. The temporay or false branches have a special layer of tissue at the base, which softens and releases them from their sockets, which are soon overgrown by the bark, so that even the scar becomes almost indistinguishable. The base of a fallen branch is marked with very fine edges and grooves radiating from the central pith, which is very small at the joint (Pl. XI). It is noteworthy from the botanical standpoint that these temporary or deciduous branches arise from the axils of leaves, while a more permanent or true branch appears as an adventitious bud at the side of the base of a temporary branch. On young trees it is very easy to distinguish temporary from permanent branches, from the fact that the latter are directed obliquely upward at an angle of about 45 degrees, while the temporary branch near which it arises is almost or quite horizontal. It has been supposed by some that all the true branches are permanent—that is, that they are not provided with the soft basal tissue which enables the others to separate so neatly; but the specimen illustrated in Plate XI shows that in one instance, at least, a branch of considerable size, and itself also branched, had been shed in the same manner as the smaller branches. The typical temporary branches seldom, if ever, attain an inch in diameter at the base, but on young trees they may be 10 or 12 feet long; while the leaves of such branches sometimes measure 18 or 20 inches in length. These dimensions are generally decreased to less than half after the tree has attained the mature branching form and is not dependent on a single axis for upward growth.

The leaves and leaf scales.—A detailed technical description of Castilla would be scarcely in place in the present paper, and is rendered unnecessary by the natural size illustrations (Pls. III to VII), which are far more effective than any description could be in conveying an impression of the details of the growing tips of the branches, leaves, flowers, and fruits.

The hairs or bristles which clothe the branch are of a dull greenish-yellow or brown color; they are sharp pointed, and with age become stiff enough to penetrate and irritate the skin of the hands like the fine spines of a cactus. Each leaf is covered, before it begins to open, by a large hairy bud scale, ribbed lengthwise (Pl. III). On falling away this leaves a narrow scar, which extends completely around the branch, but is much higher on the side away from the leaf which the scale covered. Below the scar is a row of small warts, at first white and then turning reddish. Similar leaf scars and warts are also found on the breadfruit and on the numerous species of figs.

The leaves are of a fresh light-green color. When young they are decidedly yellow below, because of the presence of numerous greenish-yellow hairs, somewhat softer than those of the branches. The fully expanded leaves appear less hairy because the hairs are distributed over a larger surface. They are most numerous on the midrib and larger veins, but are not confined to these.. The hairs of the veins near the margin sometimes project past the edge in little tufts, which give the appearance of fine marginal teeth. The base of the leaf is composed of two broadly rounded lobes, which often extend past the stem and overlap. The larger veins are very prominent; they continue to branch and subdivide until a very delicate network is formed. The veins of all sizes are more hairy than the surface between them, but this is also distinctly hirsute. The upper surface appears smooth by comparison and is a much darker green in color. The veins are not prominent above and bear but few hairs. Under a lens it may be seen that the upper surface is not really smooth, but is set with very short pointed hairs, which render it rather rough to the touch.

The flowers and fruits of Castilla.—The flowers of Castilla are of two very different kinds. Both usually occur on the same tree, though young trees often produce only the male or staminate flowers. These are shown in natural size in Plates IV, V, and VI, and consist of scaly flattened pods, opening along the edge like a bivalve shell. Inside is a mass of creamy white stamens.[a]

The whole flower or head suggests a flattened fig, opening along the edge instead of at a small aperture in the middle. A pair of much smaller and more fig-like clusters of male flowers is often attached immediately under a cluster of female flowers.

The most conspicuous difference the writer was able to find between the Castilla of Alta Vera Paz in eastern Guatemala and that of the Soconusco district of southern Mexico is in the scales of the male

[a] In Modern Mexico for March, 1903, a correspondent writing from Oaxaca, Mexico, states that the flowers of Castilla are "of a brilliant scarlet," which would seem to indicate a variety distinct from those seen by the writer, unless the deep orange color of the fruits has been confused with that of the flowers.

flower clusters. Plate IV, from a photograph made near Panzos, Guatemala, shows scales much larger and more closely appressed than Plates V and VI, from photographs taken on La Zacualpa estate near Tapachula, Mexico. The difference is especially noticeable along the margins of the valves, where the scales of the Soconusco specimens are smaller and more numerous and project more than the others, as will be seen by a comparison of the plates.

The pistillate or female flower clusters of Castilla (Pl. VI) are flattened in the other direction, and might be described as broadly top-shaped. They are covered with scales much coarser than those of the staminate flowers, and numerous two-parted styles are exposed in the middle.

As the fruits approach maturity they enlarge and spread apart until the scales which formed the sides of the young flower cluster are carried back underneath to furnish a base for the rounded-pyramidal orange-colored ripe fruits (Pl. VII). The number of fruits which are able to mature varies between 15 and 25, and these are surrounded by an equally variable number of more or less aborted fruits, which shade off into scales by imperceptible gradations. At the rounded or truncate apex of the fruit is a minute cavity in which the withered remnants of the two-parted style are usually to be found.

The scales of the flower heads are velvety, with small and very numerous hairs, but the hairs of a few scales near the point of attachment are much coarser. The fruits are also very finely pubescent or velvety, the hairs being still more numerous and shorter than those of the scales.

The flesh of the fruit of Castilla contains numerous delicate fibers. It has a faintly sweetish taste, but is without appreciable flavor. The removal of the pulp leaves an ivory-white seed about the size and shape of the chick-pea or garbanzo (*Cicer arietinum*), but more regular in shape. The white outer wall of this seed is thin and becomes brittle as soon as it has dried a little. Underneath it is a still more delicate brown coat, marked with branching lines of lighter brown. The seed itself consists of two somewhat hemispherical cotyledons, with a very small plumule near the more pointed end.

It is doubtless owing to their very thin walls and rather fleshy texture that the seeds of Castilla dry out very easily and are accordingly very short-lived. The fruits ripen and fall to the ground at the end of the dry season, and the pulp assists in keeping the seeds moist until the beginning of the rainy season brings conditions favorable for their germination.

The milk of unripe fruits.—At present the rapid increase of rubber plantations renders the seeds valuable, but it is still permissible to raise the question whether the milk with which the unripe fruits abound

may not be utilized. The fruits are produced in large quantities and, if the seeds were not in demand, would be of no value to the planter. The aggregate amount of milk they contain must be considerable, since on the slightest injury a large drop of creamy liquid exudes. This continues to be the case as long as the fruit remains green, but as soon as it turns yellow the milky juice disappears except from the seed itself. Presumably it is changed, as in figs and in the fruits of the family Sapotaceæ, into the juices which render the pulp attractive. The birds are apparently fond of the ripe fruits of Castilla. To dry the fruits gradually would probably mean the destruction of the rubber in the same way as in normal ripening, so that it might be necessary to cut or crush the fruit clusters to induce prompt drying, or to extract the milk and other juices by pressure, followed by washing and the separation of the rubber.

In case it should be found that rubber could be obtained from the unripe fruits, it would probably not be necessary to pick them by hand. They are so attached along the simple branches (Pl. XVIII, fig. 2) that several of them could be brought down by a single motion of a forked stick.

Prussic acid in Castilla seeds.—In examining the fresh seeds of Castilla a distinct odor of prussic acid was noticed, a fact which may have bearing upon the physiology of rubber, since the same substance occurs in the seeds of Sapotaceæ, the family which furnishes gutta-percha, and is also known to exist in the rubber-yielding genus Manihot, of the family Euphorbiaceæ, to which the Para rubber tree, Hevea, also belongs.

SPECIES AND VARIETIES OF CASTILLA.

HOOKER'S MONOGRAPH OF CASTILLA.

Sir Joseph Hooker wrote what might be termed a monograph of Castilla in 1885,[a] in which four species or varieties were described, though no new botanical names were assigned to them. The characters of the fruits were chiefly relied upon, and these are described as follows:

I. *Castilloa elastica.* Fruiting receptacle (in Honduras specimens) 1¼ to 2 inches in diameter; ripe carpels coriaceously fleshy, with pyramidal free pubescent crowns one-third inch high; crown 3 to 4 grooved laterally, with rounded angles and obtuse depressed 4-lobed tips. Seeds one-fourth to one-third inch in diameter; more or less immersed in the free crown of the carpel; testa white, papery when dry; cotyledons thick, plano-convex; radicle minute, superior.

The character by which I identify this with the plant of Cervantes is that of the free part of the ripe carpels, which that author describes as "apice excavato;" in all the other forms noticed below these crowns are acutely 3 to 4 angled, with acute tips.

[a] On the Castilloa elastica of Cervantes, and some allied rubber-yielding plants. Trans. Linn. Soc., London, 2d ser., **2**:209.

The reduced figure of the fruit given by Cervantes shows the character of the grooved sides and rounded angles of the carpels, but not their indented tips.[a]

II. The Caucho, or Darien plant. Leaves less thickly tomentose beneath. Fruiting receptacles 2 to 3 inches in diameter; crowns of the ripe carpels prominent, pyramidal, acute, acutely 3 to 4-angled. Seed one-third inch in diameter, more or less immersed in the free crown of the carpel.—Darien, on the Chagres and Gatun rivers.

III. Fruit referred to Ule, from the Belize Estate and Produce Company. Fruiting receptacle 1 to 1¼ inches in diameter; crowns of the ripe carpels prominent, acute, acutely 3 to 4-angled. Seeds one-fourth inch in diameter, more or less immersed in the free crown of the carpel.—Honduras and Nicaragua. This appears to be a small-seeded variety of the Darien species.

IV. Fruit of the Tunu or gutta-percha yielding plant, from the Belize Estate and Produce Company. Fruiting receptacles 2 to 2½ inches in diameter; crowns of ripe carpels very low, subacute, acutely 3 to 4-angled. Seeds one-third inch in diameter, immersed in the receptacle far below the crowns of the carpels.—Spanish Honduras.

COSTA RICAN SPECIES OF CASTILLA.

According to Koschny, four species of Castilla exist in the forests of Costa Rica, three of which yield rubber, while the gum derived from the milk of the fourth is not elastic, but becomes brittle and resinous. The general shape of the trees and their branches and leaves are said to be the same in all four kinds; the differences enumerated are those of the bark, the colors of which give the names to the three rubber-producing species.

Castilla alba, hule blanco, or white rubber, has a smooth bark which appears reddish white from a distance, owing to the presence of a thin white lichen. With age it becomes covered with coarser lichens and mosses and very difficult to distinguish from other forest trees. The bark and bast layer are thicker and softer than those of the other species; it is the most tenacious of life, and yields the most rubber. The milk is a thick fluid, and only about half of it runs down unless it is helped by the fingers; the rest remains in the cuts and dries down in six or eight days unless washed out by the rain while still fresh. Thus the tree does not easily bleed to death. The hule blanco is never found in the denser forests, but is abundant in more open places where the leafy crown can be exposed to the light and at the same time sufficient cover remains for the trunk. It is the only species suited for cultivation.

Castilla nigra, hule negro, or black rubber, has bark which is very rough and dark; also somewhat thinner, tougher, and more fibrous than that of *Castilla alba*. It gives considerable milk, but thinner and more fluid, and the tree often bleeds to death. On account of this greater susceptibility to injury it is not to be considered for cultivation. This species appears only in the undisturbed forests and is a true shade species. It is said also to occur with the other species, but is much less abundant, because it has more often died out.

Castilla rubra, hule colorado, or red rubber, has a bark so different from the others that it would not be taken for a rubber tree were it not for the other characteristics. The bark is distinctly thinner than in other species and the last layer is inconspicuous.

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[a] The range of the typical *Castilla elastica* is given as Mexico (south of 21°), Guatemala, Salvador, Honduras, Nicaragua, and Costa Rica, and the tree described by the Danish botanist Liebman as a distinct species, *Castilla costaricana*, is held to be the same.

Along the channels made by tapping it crumbles or easily separates. Externally it is smooth and has a reddish shimmer, especially on the branches and young trees. In contrast with that of the previous species it does not become fissured lengthwise, but is separated into transverse bands by shallow grooves. The bands, in turn, are beset with small reddish warts arranged in vertical and horizontal rows. Nevertheless, with the exception of the warts, the surface of the bark is quite smooth, without fissures of any kind. This species occurs frequently mixed with the others, usually less abundant than the white, but sometimes predominates. It may be that this is the cause of the poor results attained in the experimental gardens of Java and Ceylon, and that these were the more unpromising because this species requires to be shaded more than the white, but was probably planted in the open.

Castilla tanu, or hule tanu, is also called "gutta-percha" by the rubber gatherers. The bark is grayer but otherwise is very similar to that of the white Castilla, with which the leaves and habits also agree. The species is to be distinguished principally by the more prominent root folds or buttresses of the base of the trunk, which are distinctly thinner than with the other species; the upper edge is also thinner and sharper. This species does not occur in the San Carlos Valley, but first appears in the neighborhood of Bluefields on the Mosquito coast. On the Pacific coast it is in places very common. The milk flows in abundance, but becomes hard and resinous on drying. Although of no use as an elastic rubber it is possible that it might be adapted to some purpose, especially after the separation of the resinous constituents.

These summaries of Koschny's descriptions include all the distinctive points mentioned by him in order to facilitate the further study of the subject and also to make plain the difficulty which the planter would have in securing seed of the right kind, since the seeds of the different species are said by Koschny to be quite indistinguishable.

FIELD NOTES ON CASTILLA IN GUATEMALA AND SOUTHERN MEXICO.

Castilla probably grows wild in all the tropical forests of Guatemala, with the exception of those which are too wet. It is also found at considerable elevations, but the yield of rubber falls off as the altitude increases. In the Coban district of Alta Vera Paz there have been several experiments in rubber planting, but the altitudes are probably too great, and the coffee districts too continuously humid for good results; consequently rubber culture is now attracting little attention.

In the coast belt and the valleys of the Polochic and Motagua rivers several rubber-planting enterprises have been undertaken and abandoned. Only scrap rubber is obtained from either wild or cultivated trees. Either the milk is not produced in the same abundance or it is not held in the tree under the same pressure as in the rubber trees inspected later on the Pacific side of southern Mexico. It may be that two varieties of the trees differ in this respect as well as in the scales of the male flowers, as described above.

According to Hon. James C. McNally, consul-general of Guatemala, the productive rubber districts of Guatemala lie in the region about La Gomera, on the Pacific side near the coast. The low grade of the Guatemalan rubber as it comes to the market is explained by the fact that a very large proportion of it is stolen by professional rubber

thieves who let the milk run down into a hole which they dig in the ground, thus allowing it to take up earth, stones, rotten wood, dead leaves, and other impurities. The planting of rubber trees as a regular industry is just beginning, but plans are being made for several large estates. Trees are said to have grown 21 feet in two years, and one tree (age unknown) is said to have produced 6 pounds of rubber. It is believed in this part of Guatemala that young trees do better when planted in the shade. The dry season in the Pacific coast districts is long and rather severe.

About Panzos and elsewhere in eastern Guatemala, Castilla had only begun to blossom at the time of our visit (April 4), but about two weeks later (April 20), on the way down from Guatemala City to the tropical belt of the west coast, the fruit of Castilla was found to be already ripe. The first trees were seen along the railroad below Escuintla, and others were found at San José. This would seem to indicate a much earlier season for rubber on the west side. Perhaps Castilla begins to form its blossoms at the opening of the dry season, which comes earlier on the Pacific side.

A few miles below Escuintla is a small orchard of rubber trees which must be at least ten or twelve years old. They had been tapped, but not extensively, and the experiment had apparently not been deemed promising enough to call for extension. A few Castilla trees were seen along the railroad between Ocos and Ayutla, and they became more frequent after crossing the Mexican border on the road between the last-named town and Tapachula. In the vicinity of Tapachula and again between Tapachula and La Zacualpa wild Castilla is very frequent in favorable situations in all uncleared tracts. In the forests about La Zacualpa, Castilla is a very common tree.

Along the road between Tapachula and the port of San Benito many Castilla trees have been planted, and in one place there is quite a long avenue, the rubber trees standing in a hedge of sour orange. These trees, although large and vigorous, are said to yield little or no rubber. The local explanation is that the soil of this neighborhood is a sort of hardpan not suited to rubber production.

Wild trees of Castilla were occasionally seen in the rather open forests near the coast, about San Benito, where palms of the genera Inodes and Attalea are also abundant. The rubber trees were small and rather spindling. One tree 4 inches in diameter "bled" freely when cut with a pocketknife. There had been rain the previous night. This coast region may have been originally forested with dense tropical growth, but this is probably not the case with the Inodes and Attalea districts. Some desert plants, such as wild crescentias, are found in the open places, but the woods are often thick. The land is very level, the upper layers probably washed down from the interior mountains and deposited on the beach sand.

No wild rubber was seen on the Isthmus of Tehuantepec between Juile and San Juan Evangelista. The vegetation here indicates a climate dryer than that in the vicinity of Tapachula. The somewhat more hardy plants of the rubber belt, Cecropia, Cochlospermum, Attalea, etc., are present, but the new elements are of the small-leaved desert or dry-climate types, with none of the humid tropical proclivities of the Tapachula region. The forest growth is also much smaller and the woods are more open.

Two small trees of Castilla were seen midway between San Juan Evangelista and San Miguel, on the new branch of the Vera Cruz and Pacific railroad. They were closely similar to the Pacific coast sort, but appeared rather unusually well fruited for young trees, and the individual ripe fruits seemed exceptionally large. The trees were slender, 4 or 5 inches in diameter, and had not been tapped. The country between the two points mentioned becomes more and more open; grazing is the only industry. There are occasional Attalea palms in the moister spots along streams, but Acrocomia is the only common palm. Acrocomia may be taken as a good counter-indication of wild Castilla, which seems to flourish only where there is more moisture and a vegetation more luxuriant than Acrocomia can compete with.

Both to the south and to the north of Perez station rubber trees grow wild, though they occur but sparingly, and all are of very small size compared with those of Soconusco, in keeping with the general reduction of the size and quantity of the forest growth, due probably to inferior soil and drier climate.

In one instance a large number of trees was seen in a small clump or thicket only an acre or two in area, but notwithstanding the almost complete exposure of many of the trees they were still of very slender habit. When young, however, they doubtless had undergrowth to contend with, but had been able to get well above this, owing to their greater vigor. There is no indication that rubber trees were ever abundant in the region about Perez. This view is also supported by the fact that the existing trees have not been killed or dwarfed by tapping, as in regions where the trees are sufficiently large and numerous to make rubber gathering profitable. That Castilla would grow, if planted, in the open grass land about Perez is very probable, but that it would thrive is not so likely, owing to the absence of the rich soil in which it prefers to grow, as seen in the more southern districts.

The oldest planted rubber trees in the Cordoba district of Mexico are said to be near Tierra Blanca. They are about 9 years old, and were to have been tapped experimentally in June, 1902. Sir Wetman Pearson, the English builder of railroads and harbors on the Isthmus of Tehuantepec, also has a plantation of about 100,000 trees of similar age.

The reported permanent moisture of the rubber district of the Isthmus of Tehuantepec is counter-indicated by the fact that the rubber

trees uniformly drop their leaves very completely, both young and old, in the nurseries, as well as in the plantations. Many other of the native trees also drop their leaves in the dry season.

It was learned that there is a so-called *hule macho* in the vicinity of Trinidad and Buena Vista. It is recognized as having a fruit of a different shape from that of the true rubber tree, but it is generally thought to be the same. Seedlings of *hule macho* appear in plantations sown from seeds of wild trees collected in the neighborhood, which may obviously have come from wild *hule macho*, though it is commonly believed that they are the male sex of the rubber tree.

All the wild Castilla trees seen in the forests of Guatemala and southern Mexico might be described as of medium rather than of large size and of slender habit. The largest was near Tapachula (Plate IX), with an estimated height of 80 feet and a circumference of 7 feet at 5 feet from the ground. There can be no doubt that in some of the drier districts of the Isthmus of Tehuantepec and northward Castilla shares the reduced size and somewhat stunted growth of the tropical vegetation, which is here approaching the limit of its natural range. On the other hand, it can scarcely be doubted that in the more southern of the Central American Republics trees of Castilla attain a size unknown in Mexico. Thus, in Nicaragua, Belt speaks of trees 5 feet in diameter which yield as high as 50 pounds of rubber when tapped for the first time. Such a tree would of course be a veritable prize for the rubber gatherer, and it is easy to understand that in most localities they have all been destroyed, and with little prospect of being replaced as long as the rubber gatherer remains vigilant and the forests are unprotected. Whether the Castilla of Nicaragua and Costa Rica is the same species as that of Mexico is not yet known, but there is every probability that differences of some kind exist, and these are quite as likely to be differences of yield or of quality of rubber as discrepancies in shape of leaves or other merely "botanical" characters. As soon as planters realize that a paying quantity of rubber is not, as so many have supposed, a necessary part of the economy of a tree they will better appreciate the fact that the production of rubber is a cultural problem as truly as the production of coffee or sugar and as dependent upon the same general factors. The conditions must be suitable for the plants and the plants suitable for the conditions. No plant variety will do equally well under all conditions, and it is almost as universally true that no two varieties will do equally well under the same conditions.

HABITS OF CASTILLA IN THE WILD STATE.

There is a popular impression that in order to domesticate a plant it is necessary to place it under the same conditions as in the wild state, but as a matter of fact our cultivated plants generally have much better

conditions than their wild relatives. It is easy, however, to overlook some essential requirement of a new culture, and it is a distinct advantage to understand as thoroughly as possible the habits of a wild plant which it is desired to domesticate. The tamarack and the cypress, for example, are in nature confined to swamps, but they grow as well or better when planted on dry ground. The difficulty is that without human assistance they are unable to establish themselves on dry ground. Similarly, it has been inferred regarding Castilla that it is a shade-loving plant because it is found wild only in the forest. It is known, however, that it is thus limited in nature because the seed is so thin-skinned and short-lived that there is no possibility of its surviving exposure to the open sun on dry ground, and it is abundantly proved that young trees planted by man in the open are able not only to resist exposure to the sun, but that they actually thrive better than those planted by natural agencies in the forest. This fact should be sufficient for the purposes of practical agriculture, unless there are reasons for believing that more rubber can be produced in the forest. This is sometimes argued on the ground that Castilla is a native of dense forests and can not be expected to yield as much rubber under other conditions. If, however, it is true that Castilla, or at least *Castilla elastica*, is not a forest tree in any extreme sense of the words other reasons will be needed to justify shade planting.

THE RUBBER TREE AND THE TRUMPET TREE.

Castilla is a relative of the trumpet tree (Cecropia) and has a similar place in the general economy of nature. Cecropia is widely distributed in the Tropics, but is not looked upon as a true forest tree. It is what might be termed a tree weed. It shoots up with great rapidity, and is able for a time to keep ahead of the other vegetation which in most tropical countries promptly takes possession of land neglected after cultivation. Cecropia is thus one of many plants which have received indirect advantage from man's agricultural operations, and it is seldom found in great abundance except where larger growth has been cleared away. In the undisturbed forest it can not withstand the competition of the long-lived hard-wood trees and is found but sparingly, being limited to openings made by fallen timber, forest fires, changes of river channels, and other accidents which give it an opportunity for growth. The same appears to be even more true of Castilla. Scattering trees are probably to be found at greater or smaller intervals throughout the forests of low elevations, but there seem to be no indications that they exist in numbers except in forests of rather open growth, such as those which produce also the large palms of the genus Attalea, and which there is reason to believe do not represent a truly primeval condition or one of complete forestation, though the last clearing may have taken place centuries ago.

CASTILLA NOT A GENUINE FOREST TREE.

The native population of the Central American region is commonly supposed to have been much more numerous previous to the Spanish conquest, and the numerous and widely distributed ruins prove the former existence of relatively civilized communities in localities which even in the time of Cortez were apparently forgotten and overgrown with forests as they are to-day. But notwithstanding the former civilization of these regions, there seems not to have been found anywhere in Central America an indication of permanent agriculture, such as terraces, walls, or irrigating ditches. The agriculture of the ancient Indians was probably like that of the modern, in that each head of a family cut down and burned each year a new piece of forest to plant his farm or "milpa." Where the population is large and old forest is no longer accessible the second and successive growths are cut at intervals of a few years until the tropical rains have washed away all the fertile surface soil and the district becomes, for the time, a desert, and is abandoned by its human inhabitants. Such deserted country is covered first by a coarse grass and then by a scattering growth of pines, which are in turn crowded out by an invasion of tropical forest vegetation, at first in the more sheltered and humid ravines and valleys and then over the whole area. At low elevations the trumpet tree and Castilla form a part of the vanguard of the new growth, and the Attalea palm is its most striking species. But it is only a question of enough time for these and their accompanying species to be overcome and well-nigh exterminated by what may be termed the permanent forest.

When one sees the Indians of to-day clearing, burning, and planting precipitous and scarcely accessible cliffs it becomes easy to believe that little fertile land in Central America, if any, is occupied by truly primeval forest, and easy also to understand that the abundance and wide distribution of Castilla may depend upon human activity even more than upon natural agencies. Arguments based upon the assumption that Castilla is a genuine forest tree may accordingly be dismissed as of little agricultural significance.

Mr. O. H. Harrison, manager of the rubber estate at La Zacualpa, was much interested in this view of the place of Castilla in nature, because he had already noticed that clusters of wild Castilla are met with in the forest only where some natural or artificial clearing had been made. Moreover, an examination of the literature of rubber shows that the facts are not new, though their significance has been concealed by the explanation which accompanies the following original account of the details learned from the rubber gatherers of Nicaragua:

> The trees prefer humid and warm soils, but not marshy, clayey, or gravelly ground, and the presence of these trees is looked upon as an indication of a fertile soil. It is not distributed irregularly through the forests, but sometimes in little groups, more

or less isolated, such a group being termed a *mancha* (spot). This grouping is the normal state, and is believed to be caused by monkeys dropping the seeds near an isolated tree, as they are very fond of the pulp by which the seeds are surrounded. The trees are distributed in vetas (veins) or bands, either in a north-to-south or east-to-west direction, the first probably caused by monkeys, by the trees being on a declivity, or by water, and the second by the wind, which daily blows in that direction. This irregular distribution has led M. Levy to the opinion that in cultivation they should be interspersed between other trees rather than form separate plantations, as he thinks that this sympathetic and antipathetic tendency should not be lost sight of. The hule is often near water courses, and nearly always on the banks. Trees of small groups give a better net produce than those composing large groups.[a]

From the scientific standpoint these explanations appear quite inadequate, since the causes which they suggest are those which are in continuous operation, and if effective in spreading Castilla at the expense of other forest trees would have given it a general preponderance long since. All the facts are, however, comprehensible on the supposition that the growth of Castilla depends upon opportunities which are relatively infrequent in undisturbed forests, as compared with regions inhabited by the Indians and subject to their primitive agriculture.

IMPROVEMENT OF RUBBER TREES BY SELECTION.

Instead of being able to dispense with agricultural knowledge, skill, and caution, the rubber planter needs an extra supply of these, since, without the advantage of adequate experience, he has the added responsibility of choosing favorable natural conditions, applying correct cultural methods, and securing the plants most suitable for the circumstances under which he must operate. That American planters have given their attention so exclusively to Castilla, and those of the East Indies to Hevea, is not the result of any demonstration of the cultural superiority of the one tree or the other, and the desirability of many other species reported as promising remains to be determined. It is entirely possible that no one species will be found to have a superior value under all conditions and be planted to the exclusion of all others. Rubber, like starch, is produced in nature under varied conditions, ranging between deserts and swamps. The number of cultivated rubber plants will probably never equal that of the starchy cereals and root crops; but there is the same practical reason why the cultural requirements, hardiness, vigor, and productiveness of the different rubber plants should be considered, and not merely those of the distinct genera and species, but those also of the differing varieties or races into which each species will be found divisible by cultural selection.

It has been found possible with many plants to increase the average percentage of starch, sugar, or oil through the planting of selected seed or cuttings, and there is every probability that the same will be

[a] Collins, Report on Caoutchouc, pp. 14 and 15.

true of rubber. In fact, the great variation in the amount of rubber both in wild and in cultivated trees is itself an indication that a ready response to selection may be expected. The selective improvement of trees propagated from seed is, however, a very slow process, owing to the time required to bring the generations to seed-bearing maturity. With Castilla much more prompt results could be obtained by the use of cuttings made, of course, from true or permanent branches. It would be excellent policy on the part of planters to set as large a part of their plantations as possible with cuttings from their most productive trees, and to watch for the best "milkers" in each generation, just as the sugar growers test the sugar content of individual canes and of individual beets which are to be used for propagation. The selective improvement of rubber plants may be pushed forward without waiting to find out what the function of rubber is or what determines its formation in the plant, since all that the planter needs to know is that rubber is present in more than average quantity in certain of his trees, and he may expect that by propagating from these under the same conditions a higher average of production may be secured.

PROBLEMS PRESENTED BY THE LATEX, OR "MILK."

Of what use is the rubber milk to the trees, or why do the trees make rubber? These are the questions which seem to underlie the scientific investigation of the cultural production of rubber. At first it was taken for granted that the elaboration of rubber is the special function of the rubber tree, an idea apparently indorsed by some of the tree-planting companies in such statements as the following:

> You can no more grow a rubber tree without the rubber milk in it than you can grow a sugar-maple tree without the sugar sap in it. The growing of rubber trees in their own soil and climate is just as practical, just as safe, and just as sure as gathering elm seed and growing elm trees therefrom.

Rubber is not, however, the fruit of the rubber tree, except in the financial and commercial sense, and even the slightest experience in agriculture should have prevented the inference that because a plant thrives when young it is certain to reach a productive maturity. Many of the early experimenters in rubber culture have found to their cost that the Central American rubber tree, at least, can grow with the most promising vigor and yet fail to deliver any approximation of the estimated quantities of gum. Indeed, this fact might have been learned with vastly less expense of time and money by consulting the native rubber gatherers, who are thoroughly aware that many "ule" trees give no return for tapping. The realization of this simple and fundamentally important fact has been delayed through existence in some of the Central American rubber districts of a second species of Castilla," called by the natives "ule macho," or "male rubber," because it gives little or no milk.

Possibly owing to the suggestion of the obviously distinct sexes of the tropical papaw, or melon tree, the idea of sexuality in plants is widely prevalent among the aborigines of tropical America and their Spanish-speaking descendants, who thus have in the word "macho" a ready explanation of unproductiveness.

Perhaps it has never occurred to any of the native rubber gatherers to insist that the white man should understand the difference between the "*ule macho*," which is a distinct species (*Castilla tunu*), and the "*ule*" termed "*macho*," because it does not yield milk, though not in other respects different from the productive trees. Again has a little learning proved dangerous, in that the existence of a sterile species of Castilla has served as a general explanation of differing yields of rubber, the true causes of which still remain to be discovered.

That varietal and individual differences of yield will be found inside the genuine rubber-producing species is, of course, to be expected, but there is also every probability that conditions, whether natural or artificial, may have a profound influence on the all-important feature of rubber production, so that we are brought again to our original question of causes determining the formation of rubber.

EVOLUTIONARY ARGUMENTS REGARDING LATEX.

Some have insisted that the solution of the problem lies in discovering the use of the rubber to the tree, on the ground that natural selection brings into existence only useful characteristics. This theory has encouraged speculation, and numerous attempts have been made to frame a general explanation of the function of latex, or milky juice in plants. Such, however, is the diversity both of the thousands of latex-producing plants and of the substances which the various kinds of milk contain, that any explanation sufficiently general to accommodate all might have little practical bearing on rubber culture. Indeed, there is no assurance of unity of causes and methods of formation of milk in the several hundred species of rubber-producing plants of diverse families and conditions of growth, and we can even go farther and say that Castilla itself demonstrates that the production of milk and of rubber may be of no very serious importance in the plant economy, since apparently normal growth and reproduction are accomplished with little or no rubber. Furthermore, we have no assurance that the discovery of the function of the latex would bear directly upon the question of rubber production, since it does not appear that the mechanical qualities which we value in rubber, notably its elasticity and toughness, are of use to the tree or that they exist in the living latex. Commercial rubber is certainly a very different substance from the creamy mass which first appears when coagulation sets in, and numerous changes may have taken place before even this

stage is reached. Between the vegetable and animal milk no complete analogy can be maintained, but it serves to illustrate the present point if we think of the rubber not as the curd which coagulates from the milk, but as the butter which may be separated both from the curd and from the still more watery constituents of the milk. As the churned butter is different, both mechanically and otherwise, from the fat globules floating in the milk, so does rubber differ, and probably to an even greater extent, from the semifluid globules of the latex emulsion. Rubber, as such, has no function in the plant, and there is nothing to indicate that the qualities which make it valuable to us are of any significance in the vegetable economy. Furthermore, it appears that at different stages of the Castilla tree, and even in different parts of the same tree, the substance which becomes rubber may be replaced by another, which hardens with exposure into a worthless, nonelastic resin; indeed, resin and not rubber is a constituent of the latex of the numerous relatives of the rubber-producing trees.[a] It appears, then, that to trace any direct connection between rubber and the economy of the tree is likely to be very difficult, if not quite impossible, and in general reasoning on the subject the inquirer must be content to learn, if possible, the causes which influence the quality and quantity of latex in trees known to produce rubber.

FUNCTIONS ASCRIBED TO LATEX.

The nature and functions of latex in plants are difficult problems. Many dissertations have been contributed to swell the experimental and controversial literature of the subject. Many interesting details have been discovered regarding many lactiferous plants, and many suggestions and theories have been contributed to the subject of plant physiology, but thus far no very practical result seems to have been reached in this direction. Indeed, progress may have been impeded by the idea that it is necessary to postpone the investigation of concrete problems of rubber production until a general theory of the function of latex or milky juice in plants can be formed. Very different suggestions regarding the uses of latex have been defended by different investigators on the basis of studies of different plants. The first observer compared them to the blood of animals and described the globules of gum as corpuscles, a highly fanciful notion which later writers have so zealously disavowed that they have felt it necessary to deny any circulation at all. Some have held that the milk tubes are reservoirs for the storage of elaborated food materials, while others

[a] In the State of Vera Cruz, Mexico, grows a large-leaved species of Ficus, the milk of which coagulates promptly into an elastic substance like true rubber, but the elasticity soon disappears when the gum is exposed to the air and repeatedly stretched between the fingers.

believe that latex is an excretory or waste product, even to the proteids, starch, and sugar with which the milky fluid is commonly charged. Protection against insects and snails has also been urged as the function of latex. One of the most recent writers on the subject[a] reviews and dismisses all the previous suggestions apparently for the reason that none is of general validity and, after detailing numerous observations of his own, comes to the following disappointing conclusion:

> It seems impossible to discover what is their function or to ascertain if there is one function common to all laticiferous tubes until microchemical methods are vastly improved or until analyses of latex in its various stages are made.

Obviously, however, there is no reason why it must be believed that all the functions of all milk tubes are the same, or why one function should exclude another. That insects, such as leaf-cutting ants, should not be able to attack rubber trees because the gum would disable their mouth parts might be an important advantage in Central America, but would not explain rubber in African plants not subject to the depredations of these insects. The most that can be done is to learn the uses of latex in one plant at a time, without anxiety as to whether or not a general function for latex in all plants will be discovered.

THE STRUCTURE OF LATEX.

All the foregoing suggestions and many others seem to have been made before it occurred to anybody to treat the simple but fundamental question of how the rubber is formed in the milk-bearing tubes. But there is one author at last who has appreciated this point and who has discovered by a close microscopical examination of the rubber globules that each is surrounded by a thin coating of protoplasm, with a small nucleus on one side.[b] This means that the globules of rubber are produced in the same manner as globules of fat and resin, and like the granules of starch and the crystals of lime, oxalic acid, and other substances which are laid down by the protoplasm of plant cells. If the rubber appeared in the tubes merely by chemical action or because the constituent elements were brought together, this would be an indication favorable to the synthetic production of rubber in the chemical laboratory, and it would mean also that the milk is, if not a solution of rubber, at least a solution of the constituents of rubber.

There are, however, no observations to indicate that rubber exists in plants except in the form of minute globules, so that the milk resembles that of the cow in being an emulsion. The globules are not,

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[a] Percy Groom on the Function of Laticiferous Tubes, Annals of Botany, **3**: 157, 1889.

[b] Studien über den Milchsaft und Schleimsaft der Pflanzen, von Prof. Dr. Hans Molisch. Jena, 1901.

however, naked and free, but each is surrounded by a layer of protoplasm which must contribute a part of the "albuminous constituents" of the latex, if it does not supply all, though this does not make it easier to understand the recent statement of Dr. C. O. Weber[a] that such materials are not coagulated by boiling. It might be thought that the boiling coagulates the protoplasm of each globule separately and that the rubber is released afterwards and rises to the top, but Dr. Weber's statements would not bear this interpretation, though the absence of an explanation of the supposed failure of heat to coagulate any of the albuminous matter leaves the impression that this account of the details is not complete.

SEASONAL INFLUENCES ON LATEX.

No theoretical consideration need interfere with the recognition of any relation which can be proved to exist between the amount of latex or of rubber obtainable from Castilla and the climatic conditions under which the trees are found. The most direct evidence of such climatic influence is to be found in the seasonal changes in the latex. Such differences in the rubber content of the milk at different seasons has received little attention from recent writers, though it is not a new fact, since a detailed statement was published by Collins over thirty years ago:

> In Nicaragua it is found that although the hule yields the juice at all seasons, the most favorable season is April, when the old leaves begin to fall and the new ones appear. During the rainy season, from May to September, the richness of the juice diminishes. From that time to January the rain diminishes and the milk increases in richness, and the tree prepares to flower. The fruit appears in March, during which month and the succeeding one the milk is at its richest. The yield of caoutchouc contained in an equal quantity of milk would in April be 60 per cent more than in October.[b]

The increased richness of the milk in the dry season seems to be recognized in all districts where the dry season is long enough to permit the effect to become appreciated, but in localities where the dry weather in which tapping can be done is short there is at once less difference and less opportunity for it to become evident. Where the dry season is long, as at La Zacualpa, the flow of milk becomes small and tapping is deferred until some rain has fallen, when the quantity and quality of the milk are both at their best. The popular idea is that as the dry season advances the milk becomes too thick to flow, and that during the rainy season it becomes too poor in rubber to pay for tapping. The fact that the latex becomes richer during the dry season does not prove, of course, that the additional percentage of

[a] Tropical Agriculturist, 22:443, January, 1903.

[b] Report on the Caoutchouc of Commerce, 1872, p. 15.

rubber is a measure of protection against the dry weather. It may be that the rapid growth which goes on in the rainy season uses up the rubber, while the cessation of growth in the dry season permits it to accumulate. This possibility does not, however, exclude the other, but seems rather to strengthen it, since there are other reasons for believing that the possession of latex is an advantage in the struggle against drought. Several such facts were noticed during a recent visit to southern Mexico.

LATEX IN DESERT PLANTS.

The plants able to make the most vigorous growth and put out flowers and new leaves at the end of the dry season, even in the cactus deserts about Tehuantepec, belong to the genus Jatropha and are near relatives of the Ceara rubber tree, *Manihot glaziovii*. Also Prof. H. Pittier says that on the dry Pacific slope of Costa Rica the Ceara rubber tree produces rubber, but refuses to do so in the humid district of Turrialba, although it thrives well there.

In the cactus desert about San Geronimo to the northeast of Tehuantepec is another euphorbiaceous plant with naked green stems a yard or more in length and reddish unsymmetrical flowers. The stems are rich in a milky juice, which rapidly coagulates into a substance much like rubber, but lacking elasticity. The plant was quite leafless, but was blossoming at the end of the dry season. After the milky Euphorbiaceæ, the most flourishing desert plants were the Apocynaceæ, also with milky juice. The leguminous plants of the desert do not have latex, but they are noted for their richness in gums and resins, which are similarly formed and may have similar functions in the plant economy.

The most striking suggestion of the utility of latex as a protection against drought was noticed in a cactus of the genus Mammillaria, found nestling in the crevices of the bare, black rocks of the fiercely heated hillsides about Tehuantepec. The Mammillarias differ from all other members of the family in having a thick, milky juice. which becomes very sticky between the fingers, though showing no signs of elasticity. It will be difficult to avoid the conclusion that in this instance the milky juice is the special character which has enabled the Mammillaria to excel all its relatives in resistance to desert conditions of extreme heat and dryness.

A step in the same direction seems also to have been taken by a large, straggling Opuntia found near San Geronimo. Instead of the watery juice found elsewhere in this genus, a knife cut brings out a thickish, opalescent sap, which rapidly coagulates into a somewhat resinous substance and quickly seals over the injury.

WATER STORING AS A FUNCTION OF LATEX.

As already stated, the recognition of a relation between latex and dry weather has been hindered rather than helped by the attempt at framing a theory of the use of latex to the plant; but a few writers have appreciated such facts as the above, and have been inclined to look upon the storage of water as the long-sought general function. The following extract affords an instance:

> If the formation of laticiferous tubes has been called forth in all plants possessing them to perform a common function, then I am inclined to think the idea of their serving as channels for holding water in reserve as one of the most plausible. Laticiferous plants are markedly characteristic of tropical regions, where transpiration is great. The development of a system of tubes running throughout the plant to be filled with water during the wet season and then to be gradually drawn upon during times of drought is intelligible.
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> Warming, in a paper in the Botanical Gazette for January, 1899, entitled "Vegetation of tropical America," mentions lianas and other plants of tropical forest and scrub as often lacticiferous, and says: "Most likely latex serves several purposes, and one of them, I suppose, is to supply water to the leaves in time of need when transpiration becomes too profuse."
>
> From our experiments in Ceylon we found that the quantity of latex extractable from incisions in the trunks of Hevea trees varied considerably with the time of the year and seemed to depend largely upon the available moisture in the soil. After heavy rain the exudation of latex is much more copious and thinner, looking as though the vessels had become surcharged with water.
>
> As the necessity for a reserve of water increased, the laticiferous system would tend to become more extensive and more intimately associated with the surrounding tissues. The genus Euphorbia chiefly inhabits dry regions and is one of the richest in latex.
>
> This view does not explain the proteid or starch grains of latex, yet I think it is one to be borne in mind in studying the rôle of latex in plants, and hitherto it has in the main been disregarded. If latex does serve as a water reserve, then perhaps it is chiefly valuable for the growing organs.[a]

This view has, however, met with no general acceptance, and has obvious difficulties, the most important being that the amount of water actually stored or present at one time in a tree like Castilla would not long suffice for necessary transpiration. It avails little for such a plant to store unless it is also possible to husband the supply. At present, however, there seems to be no practical suggestion of means by which latex rich in rubber could better assist either in storing the water or in preventing transpiration, but of these alternatives the facts seem to be much more in favor of the latter. Apart from the slight increase due to growth, the contents of the trunk must remain of approximately the same volume. The increased pressure to which is due the increased flow of milk after the rains begin does not require a large increase of the volume of liquid in the tree, and is in all probability greatly assisted by its greater fluidity, which enables it to flow longer distances to the cuts, the capillary friction being decreased.

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[a] Parkin, Ann. Bot., **14**:212–213, 1900.

The greater humidity of the atmosphere would also tend to the continuation of the flow in the rainy season by preventing the drying or the coagulating of the surface of the cuts, though the importance of this factor has not been determined.

That the increase of the rubber content of the latex serves as a protection against drought is also rendered somewhat more probable by the fact that Castilla has several characters serving the same purpose. The development of hairs upon the branches, bud scales, leaves, flowers, and fruits is much greater than is usual among related plants. The self-pruning of the branches and the rapid covering of the scars are also exceptional and of obvious utility in reducing transpiration, and the prompt falling of the leaves in situations where the water supply becomes deficient shows even better the sensitiveness of Castilla to drought.

SIGNIFICANCE OF MULTIPLE TAPPING.

The latex problem acquires new interest from the recent demonstration that Hevea, at least, continues not only to yield milk by the daily renewal of the wounds, but that the quantity actually increases for several days. This might seem to favor the idea that the latex has a nutritive function, the additional quantities being assembled, as it were, to repair the injury. On the other hand, the supposition that the rubber hinders evaporation would also work equally well and affords the additional suggestion that the greater evaporation from the wound may assist in collecting the rubber about it, the yield increasing as the widening of the wound increases the surface of evaporation until the available supply of latex has been depleted.

CLIMATE AND RUBBER PRODUCTION.

A CONTINUOUSLY HUMID CLIMATE NOT NECESSARY FOR CASTILLA.

The study of Castilla furnishes evidence that with this tree there is a relation between climate and rubber production, and that this relation is the opposite of that commonly supposed to exist.

The vast quantity and high quality of Para rubber have naturally given Brazil the chief place in the thoughts of those interested in rubber, and it is one of the best established traditions of the subject that the native home of rubber is in the vast, periodically overflowed valleys of the Amazon and its tributaries; and the common failure to appreciate the diversity of the rubber-producing trees gave this idea very general acceptance.

Practical experiments in Central America soon showed, however, that Castilla will not thrive in swamps or where the drainage is deficient, and this fact is generally noted as a cultural difference between Castilla and Hevea, though the need of continuous humidity for Castilla is still insisted upon. The point has even been carried so far that

some of the companies doing business on the Isthmus of Tehuantepec, where there is a very distinct dry season, still feel it necessary to omit this fact from their prospectuses or to represent their plantations as always moist. The incorrectness of this claim not then being realized, the extent of the dry season of the west coast of Guatemala and the adjacent Soconusco district of Mexico was observed with much interest.

GREATER ABUNDANCE OF CASTILLA ON THE DRIER PACIFIC SLOPE.

The total rainfall of a place affords but the slightest intimation of its climate in relation to vegetation. A sudden, heavy shower may wet the soil much less than the same amount of water falling as a steady rain, and in the supply of water to plants the difference is even greater; the period during which the atmosphere and soil are moist is of importance to them, but not the amount of water which patters off their leaves or falls into the rain-gauge. Humidity even to the point of saturation for six months may be of no avail to plants unable to survive an equal period of drought. The lowland forests of the west-coast districts of Guatemala and southern Mexico, while composed in the main of the same tropical elements as those of eastern Guatemala, yet showed a striking deficiency of plants requiring continuous humidity.[a] Nevertheless wild Castilla seems to have existed in the past as in the present in far greater abundance, the wild product having long been an article of export in quantity far more considerable than from the eastern districts.

FREER FLOW OF MILK IN DRIER REGIONS.

A second fact contrary to the popular supposition that rubber production is confined to continuously humid climates was encountered when it was found that, in spite of the greater dryness, the milk flows down from the rubber trees of Soconusco with a freedom unknown in eastern Guatemala, where it merely oozes out into the gashes made by the "uleros." Dr. Paul Preuss, who studied rubber culture in Trinidad, Mexico, and Central America for the German Colonial Society, did not see rubber flow down from the wounds made in tapping, and seems to have left America in some doubt as to the reality of this phenomenon. He explains that the milk of Castilla behaves very differently from that of other rubber trees. The "fish-bone cut" to which he had been accustomed was found in Trinidad to

[a] Such are the filmy ferns, or Hymenophyllaceæ, and forest species of Selaginella; also many Orchididaceæ and Piperaceæ, largely absent from the forests between Ayutla and Tapachula, and also from the vicinity of La Zacualpa. Moisture-loving plants increase with altitude as the more humid coffee districts are approached, but at no lowland locality visited do they exist in any such abundance as in the forests of the valley of the Polochic River, in eastern Guatemala.

be useless with Castilla, since the milk flowed out as a liquid only in the first few drops and soon turned into a pulpy mass, which remained in the grooves and had to be wiped out with the finger. Dr. Preuss says:

> In a Castilla plantation near San Salvador the manager stated, on my inquiry, that there are hule trees the milk of which is completely liquid and others of which the milk is thick and does not run down. I had both kinds of trees pointed out to me, but could recognize no difference in trunk, leaves, or fruits. All the trees, which I tapped later, always showed the thick milk.
>
> In Guatemala, however, trees were pointed out to me on two plantations which, with exactly the same appearance in leaves, fruits, habits, etc., still had a completely different behavior. On tapping there flowed out in abundance a thinly liquid milk, which, however, contained no rubber, or only very small traces of it. Of such trees there were many on both plantations. They had been specially marked, and were never tapped; naturally their seeds were also not sown for new plantations. The statement that the milk of Castilla, that from which good rubber can be obtained, runs down the trunk into vessels, I have often heard asserted with positive assurance. I have never been able to convince myself of it, and can only suppose that it is a case of two different varieties, with one of which I have not become acquainted.

DECREASE OF MILK WITH ALTITUDE AND CONTINUOUS HUMIDITY.

That rubber milk is obtained with greater freedom on the drier western coast shows that continuous humidity is at least not indispensable, but it does not prove that the larger production is due to the drier climate. There may be, and probably are, differences in the trees of the two regions, though these have not been detected. But that there is a climatic element even on the west coast is made plain by the fact that as the coastal plain is left behind and the slopes increase in altitude and humidity the production of rubber gradually declines. At an altitude of about 1,800 feet on the Esmeralda coffee estate, only a few miles from La Zacualpa, wild Castilla trees apparently normal in other respects yielded milk very sparingly, while at an elevation of 2,500 feet no milk dropped from the cuts. Castilla trees grew vigorously and attained a diameter of 15 inches in twelve years at "Quien Sabe," in the coffee district above Tapachula. The trees grow naturally up to 1,500 feet and beyond. Above 1,000 feet the rubber gatherers do not expect to find much rubber. Trees planted at an altitude of 2,000 feet from seed brought from the coast do not yield rubber.

The fact that Castilla yields little or no milk in elevated situations is commonly recognized in Soconusco, though it is not necessary to accept the popular impression that the difference is due to the mere fact of elevation. The temperature being lower and the atmosphere more humid, there is less rapid transpiration of moisture and less need at once of means of resisting dryness and of maintaining the high pressure of fluids found in trees growing near sea level.

Decrease of temperature would also mean a decreased effect from dryness. If this interpretation of the function of rubber be correct, a region like the Isthmus of Tehuantepec, which might be suitable for coffee at relatively low elevations, would not for this very reason be favorable for rubber. It is also not to be assumed that a region in which the rubber tree grows wild is favorable for the production of rubber. The case is quite different from that of a seed or fruit crop. A plant is not likely to become established in a region where it can not ripen seed, but if rubber is an adaptation against unfavorable conditions, it might be dispensed with where the unfavorable conditions do not exist. That latex serves in Castilla as a protection against drought does not mean that it may not have other functions here and elsewhere. The problem of rubber culture is to encourage the formation of latex by placing the tree under suitable conditions.

In a dry atmosphere the transpiration—that is, the moisture given off by the leaves—is much greater, and as this water is taken up from the soil the amount of salts and other soluble substances taken into the plant with the water is also much increased. It is by no means impossible that substances obtained in this way are used in the formation of rubber, and if this be the case the tree would have, as it were, an automatic protective device; the drier the weather the greater the quantity of rubber-forming materials and the greater the protection against dry weather. It is possible even that the thickening of the milk might finally impede the circulation of water and be itself the cause of the falling of the leaves, as Parkin observed with the leaves of Hevea. The falling of the leaves in the dry season would thus be an indication of conditions favorable for rubber culture rather than the reverse, as some have supposed. It is not at all impossible that a rubber tree might grow best in a region where it would not yield the maximum quantity of rubber, and, conversely, it may be found that the most rapid growth of the trees does not insure the largest yield of rubber. If it be true that rubber is a dry-weather product, the limitations of rubber culture on this side are in securing enough rain to permit rapid growth. One problem would be to find out how much of a dry season is necessary for best results. Too much dry weather would mean slow growth, too much rain decreased formation of rubber, and these factors would vary even in the same neighborhood and with different seasons. The prospects of particular localities for rubber can not be ascertained by the tapping of a few trees in each at the same date or in the same month. A tree in which the pressure in the milk tubes was too low or the milk too thick to flow out in the dry season might yield abundantly at the beginning of the rains, while in a more humid locality the fluctuations would be much less.

That rubber could be obtained from one tree in the dry season and

not from another might mean merely that the former had access to a larger supply of water and was thus able to maintain a greater latex pressure. Such questions will need to be studied in detail after uniform methods of tapping and pressure measurement have been devised. This need not obscure the fact that, unless tapping be done at the most favorable date, the productiveness of rubber trees and the localities in which they grow may be misjudged very easily.

CASTILLA IN NICARAGUA.

The opinion that the production of rubber by Castilla is favored by a dry season is based, as yet, only on observations made in Guatemala and southern Mexico; other conditions and different species of Castilla may be found in the countries to the southward. Moreover, it is scarcely reasonable to expect the interested public to adopt what may appear to be a radical view of Castilla culture without understanding the basis of the current opinion that continuously humid regions are required for the production of rubber.

The Report on the Caoutchouc of Commerce, written by James Collins, and published in 1872 under the auspices of the British Government, remained for many years the most complete and authoritative statement of the subject. It was very frequently quoted by subsequent writers, and has probably done most to establish the idea that continuous humidity is required by Castilla. Collins says:

> The species of Castilloa seem to like best and thrive in thick, humid, warm forests. They abound in Nicaragua; and as I have, through the kindness of my friend Dr. Bureau, of Paris, received from M. Paul Lévy, a botanical collector in Nicaragua, a good account of their history there, it will serve to give a correct idea of their habits.
>
> The basin of the Rio San Juan is where the ule tree grows to perfection. This river is the natural vent of the two vast basins of the lakes of Nicaragua and Managua, receiving numerous tributaries, which have all their sources in the innumerable tracts hitherto virgin and unfrequented, and where the trees abound. The ground is very fertile. The district is very unhealthy; it rains for eight or nine months in the year, and the climate is very warm and humid. The trees prefer humid and warm soils, but not marshy, clayey, or gravelly ground, and the presence of these trees is looked upon as an indication of a fertile soil. . . . The ule is often near water-courses, and nearly always on the banks. [a]

CASTILLA IN COSTA RICA.

The most extensive recent publication on Castilla is by Herr Th. F. Koschny, a resident of Costa Rica, whose opinions on the subject of climate appear to be nearly opposite to those stated above. He says:

> The safest and most productive rubber plant is the *Castilloa elastica* of Central America. Its tenacity of life and adaptability to soil and climate are seldom exceeded by other trees; the same is also true of the quantity and quality of the rubber.
>
> It requires a humid, warm climate, and with respect to rainfall less depends upon the amount of precipitation than upon the distribution of it. The shorter the dry

[a] Collins's Report on Caoutchouc, p. 14.

season and the more the rain extends over the entire year the better will a locality be adapted for rubber culture; regions with a long, absolutely dry season are unsuitable for this culture. In the valley of San Carlos, Costa Rica, upon the Atlantic slope, it rains occasionally also in the dry season, and even in the two driest months, March and April. The Pacific slope of Central America has, on the contrary, a completely dry season of four months, and two months at the beginning and end with little rain. Both the wild and the planted rubber trees die there at the third tapping at the latest, in case this takes place in the dry season.[a]

If the above statement represents a general fact in Costa Rica it can only be said at present that either the climate, or the rubber trees, or both, are different from those of southern Mexico, In spite of six months of dry weather the rubber trees at La Zacualpa have reached maturity in the open sun, and have survived many and severe tappings, as shown in the accompanying illustrations (Plates I, XII, and XVI).

It may not be without significance that the conditions with which Herr Koschny is most familiar and which he considers favorable for rubber production are not those of continuous humidity, for there is a dry season of two or three months. In eastern Guatemala, an interesting example of the rapidity with which the tropical sun can dry out the vegetation was observed. Our party arrived at Panzos during a heavy rain, and rode the next day toward Senahu over muddy roads through the dripping leaves of a luxuriant tropical growth. Three weeks later the same region was dry and parched, and even the leaves of the undergrowth of the forest were shriveled.

CASTILLA ON THE ISTHMUS OF PANAMA.

The idea that the Castilla sent from the Isthmus of Panama to British India came from a continuously humid district seems not to be justified by the statements of Mr. Cross, who secured seeds and cuttings in the vicinity of Colon. He says:

> The interior of the Darien forests would frighten most people. The undergrowth is composed of boundless thickets of a prickly leaved species of *Bromelia* often 8 to 10 feet high, the ground swarms with millions of ants, and the snakes raise themselves to strike at anyone who approaches.
>
> The Caucho tree grows not in inundated lands or marshes, but in moist, undulating, or flat situations, often by the banks of streamlets and on hillsides and summits where is any loose stone and a little soil. It is adapted for the hottest parts of India, where the temperature does not fall much below 74° F. The tree is of rapid growth, and attains to a great size, and I am convinced that, when cultivated in India, it will answer the most sanguine expectations that may have been formed concerning it. I have been up the Chagres and Gatun rivers. I came out on the railway about 7 miles from Colon. I go back to the same place (the village of Gatun), from which place by the river the India-rubber forests are reached.[b]

The undergrowth of Bromelia indicates a relatively barren, open forest with a severe dry season, and this supposition is strengthened by the allusion to the ants, snakes, "loose stones," and "little soil."

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[a] Beihefte zum Tropenpflanzer, 2:119, 1901.

[b] Trans. Linn. Soc., London, 2d ser., 2:213.

ANALOGY OF THE ASSAM RUBBER TREE.

The fact that the production of rubber may fail under conditions which permit the luxuriant growth of the trees is not new, since it was recorded with reference to the Assam rubber tree as early as 1875, as shown in the following extract:

The production of different kinds of caoutchouc in India continues to engage the attention of the India Office and of this establishment. One fact in connection with it which seems to require very careful consideration has been pointed out by Mr. Mann in his report on the caoutchouc plantations in Assam. It is found that although the *Ficus elastica* will grow with undiminished rapidity and luxuriance in situations remote from the hills, it fails to yield caoutchouc. Mr. Mann concludes that no greater mistake could be made than to start plantations of *Ficus elastica* in any part of Bengal. It appears, therefore, judging from this case, that conditions which may insure the successful growth of caoutchouc-yielding trees may not be sufficient to determine their producing caoutchouc.[a]

THE PARA RUBBER TREE IN HUMID LOCALITIES.

Following the original publication of James Collins, in 1872, writers on rubber have continued to emphasize the humidity of the forests of the Amazon basin.

The Amazon Valley is remarkable for uniformity of temperature and for regular supply of moisture. From June to December is the dry season, and January to May the wet. In the dry season in November there are a few occasional showers, and during the wet season intervals of fine weather. * * * On the banks are *dense* moist forests, with caoutchouc trees interspersed. Dr. Spruce, when at Barra, in December, 1850, found that the rains had set in some weeks previous, and from December 10 to the beginning of the following February only a single day occurred without some rain. In February there were six fair days; in March, the most rainy month, only one; and to April 18 but three days of fine weather. During March the highest temperature was 84¼°; many days it failed to reach as high as 80°.

On the Solimoens, or upper Amazon, the sea breeze is not felt, and it is therefore more stagnant and sultry. The whole of the country along its banks is covered with one uniform, lofty, impervious, and humid forest. The soil nowhere sandy, but always either a stiff clay, alluvium, or vegetable mold. The vegetation is very prolific and the atmosphere densely vaporous.[b]

It is difficult to explain why the heavy rains and overflowed rivers have been dwelt upon with so much persistence and the six months of dry weather left quite out of account, particularly since it has been known from the first that the rubber is obtained in the dry season, and Collins himself states that in the wet season the milk is poor in rubber, or "too aqueous to allow of profitable collection."

The late Mr. Jenman, government botanist of British Guiana, has

[a] Report on the Progress and Condition of the Royal Gardens at Kew during the Year 1875, p. 7.

[b] Collins, J. Report on the Caoutchouc of Commerce, p. 6.

described similarly the conditions which he considered typical for *Hevea spruceana:*

The water lies in shallow pools between the trees, or is spread in sheets, when deeper, over wide spaces of ground, and the surface soil generally, especially where this tree most abounds, is hardly more firm or dense than mud. It will give an idea of its character when I say that I wore a pair of high-laced-up shooting boots, but with the best care in moving about, and stepping mostly on the more solid soil which is usually found in hillocks around the butts of trees, or on the fallen bits of wood which stretch between them, in spite of my care, I was constantly sinking to their tops and over, so that my socks were covered with mud. I am speaking, as I have said, of the wet season of the year, but even in the dry the ground continues in a very moist condition. The land is usually very densely shaded, and in many places, probably in consequence, produces very little undergrowth.

I have taken the occasion to describe rather fully the character of the land, as it is important that persons contemplating the cultivation of this species of Hevea should be well informed as to the conditions which prevail in its native haunts.[a]

It is, of course, to be expected that different species of Hevea will be found to prefer different natural conditions, but the above account, while well showing what even explorers have been expecting to find, has little real bearing in rubber culture in view of the extreme difficulty of carrying on agricultural operations in such a country. Moreover, the average maximum yield obtainable by the destruction of full-grown trees is placed by Mr. Jenman at 1 pound, which was several times greater than what could be secured by tapping.

PRODUCTIVENESS OF PARA RUBBER TREES IN DRY SITUATION.

A Para rubber tree in the Botanic Garden at Penang, on the Malay Peninsula, is noteworthy as having a reliable record of six tappings in five years, with a total of 15 pounds and 10 ounces of rubber. The tree was set out in 1886, and was about eleven years old before it was tapped. Some of the incidents, as related in the following paragraph, are not without interest:

No particular attention was paid to these trees at the time more than to the many other economic and ornamental plants that were planted in this garden that year, then in course of foundation, and it so happened that two were planted side by side on poor gravelly soil on sloping ground, which, by the subsequent cutting of a new road alongside them some years later, converted the site on which they are growing into what is virtually a dry bank. When, some ten years after these trees were planted, the questions of the best method of extracting and coagulating rubber, and the probable yield to be expected, commenced to interest the planting community, this tree as being the largest in the garden, was selected for experiments, which have been continued from time to time and the result recorded in the annual reports. There is nothing remarkable about this tree except that, as planters have often remarked, it is remarkably small for its age, but that is not surprising, considering the nature of the soil and the situation in which it is growing.[b]

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[a] Timehri, **2**:14, 1883.

[b] Agricultural Bulletin of the Straits and Federated Malay States, **1**:385, August, 1902.

Notwithstanding the apparently unfavorable conditions and the rather severe treatment to which it has been subjected, the tree is described as in healthy condition, with all its wounds healed. It has a height of about 55 feet and a girth of 66 inches, having increased from 36 inches in 1897, when tapping was commenced.

THE TRUE CLIMATE OF HEVEA.

The results of the writer's observations on Castilla were so much at variance with prevalent opinions concerning climatic requirements that the possibility of a similar error having been made with reference to Hevea naturally suggested itself, and various indications like the preceding were found in the literature of the subject suggesting that this might prove to be the case. Shortly afterwards there appeared the following quotation from a paper written by Mr. H. A. Wickham, who made the original introduction of Hevea seeds from Brazil to British India, and whose testimony is so direct and conclusive that we need wonder only that so important a point should have been so long overlooked:

> But as all the stock of plants or seed available for the planting and cultivation of this tree in the Eastern Tropics are and will be derived from direct lineal descendants of some or other of those 7,000-odd originally introduced by me at the instance of the government of India in 1876–77, it may be well if it be recollected that their exact place of origin was in 3° of south latitude, and to remember their natural conditions there. This the more so since a very general error seems to have obtained that swampy or wet lands are the fitting locality for the Hevea. This would seem to have arisen in that the "explorer" of a few years' experience would have some of these trees pointed out to him (naturally in answer to inquiries) growing scattered along in the wet margins in going up the lower Amazon or tributaries, whereas the true forests of the Para Indian rubber trees lie back on the highlands, and those commonly seen by the inquiring traveler are but ill-grown trees which have sprung up from seeds brought down by freshets from the interior.
>
> As a matter of fact, the whole of the Hevea which I procured for the government of India were the produce of large grown trees in the forest covering the broad plateaus dividing the Tapajos from the Madeira River. The soil of these well-drained, wide-extending forest-covered table-lands is stiff, not remarkably rich, but deep and uniform in character. The Hevea found growing in these unbroken forests rivals all but the largest of the trees therein, attaining to a circumference of 10 feet to 12 feet in the bole. These forest plains having all the character of wide-spread table-lands occupy the space betwixt the great arterial river systems of the Amazon, and present an escarped face, which follows at greater or less distance and abuts steeply on the igapo or bagas, i. e., the marginal river plains subject to inundation by the annual rise of the great river. So thorough is the drainage of this highland that the people who annually penetrate into these forests for the season's working of the rubber have to utilize certain lianas (water-bearing vines) for their water supply, since none is to be obtained by surface-well sinking, in spite of the heavy rainfall during a great part of the year. [a]

[a] Agricultural Bulletin of the Straits and Federated Malay States, September, 1902, pp. 476–477.

THE CULTURE OF CASTILLA.

In attempting to plan a rational culture for Castilla it will be worse than useless to insist upon all or any of the cultural measures which have been found desirable with coffee, cacao, or other tropical crops. Castilla is not cultivated for the leaves like coca, for the flowers like cloves, for the fruits like oranges, nor for the seeds like coffee. The increase of the size of the trunk and of the amount of milk contained in its inner bark are the objects of cultural solicitude.

SHADE IN THE CULTURE OF CASTILLA.

SHADE NOT A NECESSITY.

Much of the preceding discussion of the habits of Castilla and of the climatic conditions suitable to its culture may also serve as preliminary to the consideration of the question whether plantations of Castilla require the shade of larger trees or may be exposed to full sunlight. The argument that Castilla always grows in shaded locations in nature is by no means conclusive, since it is well known that many forest trees thrive better when they have the opportunity of standing alone and are free from the close competition for food and sunlight implied by forest conditions. It is also certain that Castilla is not only able to obtain an existence in the open, but that it makes much more rapid growth quite without shade than it does in the forest. If the problem were merely to secure the quick growth of Castilla, there would be no hesitation between these two methods of planting; but there are many stages between dense forest and clean culture, and the question may well be raised whether the conditions most favorable for rubber production are not to be found in some of these. Advocates of both extremes and all intermediate conditions are not lacking, so that the question of shade with Castilla bids fair to become as complicated and as extensively debated as with coffee and cacao. Moreover, as with those crops, it may be found to have no general solution, but to depend upon local conditions of soil and climate.

That rubber can be grown under forest conditions there can be no doubt, since all the natural supplies are to be credited to this method of production, but the desirability of forest planting does not necessarily follow, since it is equally certain that under the deep shade the trees grow with an extreme slowness, which would exhaust the patience of any investor. Moreover, as previously shown, it may well be doubted whether a plantation of Castilla would ever grow to normal maturity in the undisturbed forest; the indications are that only those trees survive which are able to profit by accidents to their larger neighbors and thus receive more sunlight than usually reaches the undergrowth of a dense tropical forest. In other words, regular forest planting does not mean the placing of Castilla under conditions

most favorable to its growth in nature; these are more nearly attained when the forest is thinned out or partly cut away.

Koschny, who distinguishes four kinds of Castilla in Costa Rica, says that the "hule blanco," or white Castilla, is the only one adapted for cultivation, and that this is never found in the deep forest, but in more open places, where the foliage has access to the sunlight.

Experiments with forest planting were studied in eastern Guatemala and in southern Mexico, and in both instances the young trees were at an obvious disadvantage in comparison with others planted at the same time in more open situations. Plates XIII and XIV will serve to illustrate the difference, for although the tree shown in the latter had suffered the loss of its terminal bud the number of leaves and the amount of new growth it had made was not below the average. Many individuals had hardly grown at all in six months and many had died. On the other hand, it should be explained that the trees, like that shown in Plate XIII, while they had no shade overhead were not exposed to the extent which might be implied by the term "open culture," since they stood in a clearing only a few acres in extent. The neighboring forest gave shade in the morning and afternoon, and the atmosphere was undoubtedly kept far more humid throughout the day than would be the case in a large tract of unshaded land baked by the tropical sun. They were also undoubtedly assisted by a mulch of dead leaves and brush. Trees 12 feet high were said to be only 1 year old.

It would seem, then, that one of the extreme suggestions—the planting of rubber in the undisturbed forest—is clearly inadvisable and may be dismissed from further consideration. The other extreme—clean culture—is not so readily condemned as impracticable, since observations in southern Mexico establish the fact that even single trees, standing in the open sun and with little other vegetation near them, are not only able to survive six months of dry weather, but actually remain more leafy at the end of the dry season and thus appear to suffer less from drought than those on land covered with weeds and bushes. The reason for this apparent anomaly may not be difficult to conjecture, since it is plain that a tree standing in cleared ground has a monopoly of all the moisture which rises in the soil, and may thus have a distinct advantage over one obliged to share a similar supply of water with a tangled mass of other plants which expose to the atmosphere a total leaf surface many times that of the young rubber tree. Moreover, it is also clear that the water required to supply the needs of this large amount of vegetation would greatly exceed that which escaped from the exposed surface of the soil. It is even doubtful whether a covering of low vegetation greatly checks the evaporation from the soil; it may be as great or greater

than where the surface of exposed soil is loosened by stirring and thus forms a layer which hinders the access of dry air and is a nonconductor of heat. In previous discussions of shade in the culture of Castilla this distinction between open culture and clean culture seems to have been overlooked, and the question of shade has continued to be confused with that of water supply. The statements of various writers that the leaves are unable to withstand exposure to the full sun because of their delicate texture are quite erroneous. The tree needs sunlight, and is benefited by it as long as the water supply is sufficient, but when this becomes deficient the leaves shrivel. The light is no brighter and the temperature no higher in the dry season, which in Mexico occurs in the winter months; but the dry atmosphere demands more water, while the soil supplies less.

The rapidity with which dry atmosphere takes water from a plant may be judged by the promptness with which the leaves of a broken branch wilt and shrivel, and this happens very promptly with Castilla. Many plants have developed no expedients for resisting evaporation and are accordingly confined to continuously humid regions, but Castilla, as has already been seen, is adapted in several ways for resisting drought. The leaves themselves are, it is true, of rather loose texture and have only the slight assistance of the hairs of the lower surface as a protection against excessive transpiration. The leaves suffer when they are obliged to part with more water than they can obtain, and their falling off is then an advantage because it decreases the demand for water. Thus, although Castilla is not a desert plant, the falling of its leaves in the dry season is the same physiological phenomenon which appears so conspicuously in deserts, viz, the loss of the leaves as a protection against drought. Many desert plants such as Parkinsonia, Fouquieria, Peireskia, and species of Euphorbia put out leaves for the wet season only, while most of the Cactaceæ and many Euphorbias have discarded leaves entirely and expose as little surface as possible to the air.

This digression may help to make it apparent that the planter who desires to give intelligent consideration to the agricultural question of shade should dismiss the notion that the rubber tree derives a direct advantage from standing in the shadow of another tree; on the contrary, it is probable that interference with the sunlight is always a direct disadvantage. Shade, if used at all, is to be applied and justified on the ground that it will preserve the moisture of the soil or of the atmosphere or serve some other cultural purpose. By conserving the soil moisture, clean culture may produce some of the desirable effects commonly ascribed to shade. Open culture may be, and probably is, less advisable than either clean culture or a moderate shade culture.

Open culture with relatively little cleaning at first would be more

practicable if the weeds and undergrowth cut down in the dry season could be left spread over the ground. This would do more to conserve the moisture of the soil than the same vegetation alive, but the danger of fire will in most localities forbid the use of this method of culture.

If the present question could be settled by deciding whether or not Castilla needs to be protected from the sun, it would be easy to establish the negative view; but with shade recognized as a means of influencing natural conditions of soil or climate it becomes evident that each planter will need to use his best judgment in determining what local conditions require. In Costa Rica Koschny advises the thinning of the forest by the removal of two or three trees out of every five. At La Zacualpa more are cut out (Pl. XV). Some of the planters on the Isthmus of Tehuantepec practice clean culture. No general principles will determine which is best, because no one method is applicable everywhere.

RELATIVE COST OF SHADE CULTURE.

It must be remembered, in addition, that the planter finds himself compelled to decide not what will be the best for the rubber trees, but what is the best he can afford to do for them. Is it, for example, good policy to use labor and capital in keeping a tract of planted land clean, or will more be gained ultimately if one contents himself with somewhat slower growth and improves the opportunity of planting additional tracts with trees that can also be growing? Careful comparative experiments might be necessary for an answer, and this might differ for different localities.

EFFECT OF SHADE ON FORM OF TREE.

There are great and persistent differences of shape or "habit" among trees. The Lombardy poplar and the weeping willow are not distant relatives. It is a general fact, however, that forest trees are taller and more slender than those of the same species grown in the open. The low spreading habit, which is desired and encouraged among fruit trees, is not desirable in rubber-producing species, where a large expanse of trunk is needed to supply the milk and to give opportunity for tapping without the necessity of wounding the same place too often. Castilla trees growing alone in the open often send out permanent branches 8 or 10 feet from the ground, while those in the forest may have from 20 to 40 feet of smooth trunk before the permanent branches are reached. Open-grown trees may have large spreading branches, while in the forest or under close planting the main axis of the tree continues to grow upward and the lateral branches are relatively small.

The problems of rubber culture may prove in this respect to be directly opposite to those of coffee, where the formation of much wood

in proportion to leafage is a sign of unfavorable conditions or of bad plantation management. It does not follow, however, as some have seemed to suppose, that forest shade is necessary to grow long-trunked trees. In coffee culture it is plain that the most wood is formed not by shade culture, but by planting close in the open, and the older-planted trees of Castilla at La Zacualpa, if not as slender and as smooth-trunked as those of the forest, are certainly tall and slender enough to furnish ample evidence that open culture does not cause a low, spreading growth, if the trees stand close enough together (Pl. I). The Zacualpa experiment is of further significance in this connection, because it shows that a harmful degree of crowding was by no means reached. In numerous instances where from three to five (Pl. XII) trees grew in a cluster their trunks were each equal in size to those of many of their neighbors which stood alone.[a]

Coffee trees which stand too close together lose the use of their lower branches, which become interlaced and shade one another, and ultimately only the top of each tree continues to grow and produce fruit. The planter must choose a middle course between the injury of his bearing trees by crowding and the waste of capital and labor in keeping clean unused land between trees planted too far apart. With the rubber tree the seed is a consideration entirely secondary to the growth of the trunk. In comparison with coffee it may be said that the crowding of rubber trees is desirable, and that it finds its limit, not in the discouragement of lateral branches, nor even in the lessening of the size of the individual trees, but in the decrease in the amount of rubber which can be produced on a given area of land.

SHADE AND RUBBER PRODUCTION.

The general question of shade can not, however, be treated as closed until its influence on the yield of rubber has been tested by careful experiment. From the facts given on previous pages it appears very improbable that less rubber will be formed in the open than under shade; the difficulty, if any, is likely to arise in connection with the extraction of the rubber. The desirability of tall trunks to afford a large tapping surface has been noted already, but there may be other disturbing factors. The pressure of the liquids inside a tall columnar trunk may be greater than if it were thicker and shorter, so that more milk would be forced out on tapping. The bark of trees more exposed to wind and sunlight becomes thicker and there may be differences in texture which would affect the flow of milk. The air is much drier outside than inside the forest, and this might soon impede the flow of milk, though this suggestion seems to be negatived by the fact that

[a] Planting in clusters might be advisable on some accounts, since the trees would better shade their trunks and the ground under them, but the difficulty of properly tapping such trees would seem to exclude this method of culture.

milk flows more freely from wild Castilla on the dry Pacific slope of Mexico and Central America than in the more humid districts of the Atlantic side.

A recent writer on the shade question claims to have discovered that, while planting under partial shade hinders the growth of the trees, it greatly increases the yield of rubber. The managing director of a rubber plantation operating in Mexico writes as follows to the India Rubber World:

> We are planting in the partial shade; a great many planters are planting in open sunlight. My honest opinion is that every one who has planted in open sunlight will get a tree 50 per cent larger in five or six years than we in the partial shade. On the other hand, we will get from 60 to 75 per cent more rubber from a small tree than they do from a large one. About three months' careful study was made of this proposition; the trees were tapped both in the shade, partial shade, and open sunlight, and the results carefully tabulated by a committee of which I was not a member.

It is easy, however, to understand how such an opinion could be formed if the experiments in tapping were made at a time when the trees planted in the open were drier than those in the shade, and such a difference would be especially pronounced in young trees. This observer did not find that the milk was richer in rubber in the shade, but merely that at a certain time more milk flowed from the shaded tree than from the unshaded tree. This would not, however, be an argument for shade planting unless it were shown that the unshaded trees would not at any other time yield more milk. It is quite probable that shaded and unshaded trees might need to be tapped at different times to secure a maximum flow, or it might be found that unshaded trees could be tapped with impunity more frequently than the others, and thus afford a larger annual yield. The flow of milk does not depend so much upon the amount in the tree as upon the pressure existing at the time the tree is tapped. The indications are that pressure attains its greatest intensity in trees which are exposed for a part of the time to a relatively dry atmosphere and which are accustomed, as it were, to pump water rapidly to supply the leaves. Such trees may, on the contrary, yield no milk at all when the water supply is deficient. It may be expected, therefore, that open culture will require much more careful attention to the time of tapping. This may prove a disadvantage if it requires all the trees of a large plantation to be tapped on the same day or in the same week, but this is not likely. On the other hand, tapping at the right time would mean the drawing of a larger amount of milk from a smaller cut, a saving of labor, and a lessening of injury to the trees.

The above considerations make it easy to understand also that writers acquainted with humid districts commonly refer to the rubber harvest as occurring in the dry season, while in the drier regions, as in Soconusco, the beginning of the rainy season is the recognized time, when the tree's demand for water is largest and the internal pressure highest.

LEGUMINOUS SHADE TREES TO BE PREFERRED.

Where the policy of thinning out the forest is followed the question arises as to which trees are to be left and which cut down. A study of coffee and cacao culture has revealed the probability that much of the benefit ascribed to shade is due in reality to the nitrogen furnished by the bacteria of the root tubercles of the leguminous trees which are preferred in all countries where the shade culture of coffee has become popular. If shade trees are to be planted with rubber, they must be different from the species of Inga which are preferred for coffee shade in Mexico and Central America, for the reason that Castilla grows faster than Inga. Some leguminous trees, however, grow with great rapidity and may be able to outstrip the rubber. No comparative experiments seem to have been made. If, as suggested above, shade trees are more useful as windbreaks than for the shadow they cast on the rubber, the planting of fruit trees like the mango or other useful species in rows or hedges would be preferable to scattering them amongst the rubber.

DISTANCE BETWEEN TREES.

As yet there have been no experiments yielding any definite information on the above point, but the recent trend of opinion among planters seems to be distinctly in the direction of closer planting. There has been a gradual decline from 20 feet and upward between trees to 12 feet and under.

The questions of shade and of distance between trees are closely related and need to be considered together because several of the arguments for shade can be met, wholly or partially, by close planting. The first of these is that of the greater expense incidental to open culture. The frequency with which the land requires to be cleaned and the period of years during which it would be necessary to continue such cleaning depends largely upon the amount of overhead shade present to discourage the undergrowth. Some planters on the Isthmus of Tehuantepec are evidently taking advantage of this fact and are setting close, with the intention of removing alternate trees before they are large enough to injure their neighbors by crowding; and it is expected that if they are "tapped to death" they can be made to yield enough rubber to more than cover the expense of planting. At least there seems to be no reason why, if the land is to be cleared, it should not be made to produce as much rubber as possible instead of being planted with useless trees for a purpose which can be attained quite as fully by setting the rubber trees closer together.

There is danger, however, that any suggestion which promises earlier returns from rubber culture will be overdone. The rubber of very young trees is of low grade and expensive to collect; also it

would be very poor policy to risk permanent injury from weak spindling growth, which overcrowding would undoubtedly cause. More is likely to be lost than gained by trees standing at less than 8 feet for even a few years. Better than uniform close planting would be to set the north and south rows farther apart than the trees in the rows. With a given number of trees this would secure the maximum of shade on the ground, because the morning and afternoon sun would not shine down the rows. The cleaning of the land or the cultivation of a catch crop or a shade crop between the rows would also be facilitated. The distances would depend on the size which the Castilla trees were expected to attain in any given locality, the rows from 12 to 20 feet apart, the trees from 8 to 12 feet in the rows being fair average estimates.

METHODS OF CLEARING LAND FOR RUBBER PLANTING.

The question of shade is also involved with that of the method of clearing the land. It is an almost universal custom in tropical countries to clear land by burning the dried forest growth which has been cut down. In fact, the primitive agriculture of the natives of tropical regions could scarcely be conducted on any other basis. There is much loss of fertility by the destruction of vegetable matter and humus, but the amount of labor required to thoroughly clear a piece of forest land in the Tropics is prohibitively great. The fire not only removes the tangled mass of brush, but it performs an even more useful service in killing the stumps and roots which would otherwise reoccupy the land with new growth in a few weeks, and would remain indefinitely to dispute possession with anything which might be planted. To grow a herbaceous crop on unburned land under such conditions would be extremely difficult, but a tree culture is much more feasible, though whether the method of partial clearing is to be generally advised is not so certain. The gain, if any, is more likely to be found in the sustained fertility of the soil than in any saving of labor in clearing and cleaning the land; for although there may be a saving at first which will permit an enterprise to reach a paying basis sooner, yet there is in prospect a long and expensive struggle with the persistent natural vegetation rooted in the soil. Moreover, it should be recognized that the conditions under which a plantation is set out in a partially cleared forest are of necessity only temporary. Many of the forest trees will not long survive the unwonted exposure to greater dryness and heat and to the attacks of parasites. The thinning of the forest greatly increases the force of the wind against the remaining tall trees, and in falling these will injure the rubber trees and will often require to be cut away not merely at one point, but at several points. Whatever the merits of the case from the standpoint of the stockholder, the plantation manager of the future is very likely to wish that his predecessors had adopted clean culture. The overhead shade which discourages

the undergrowth will also discourage the rubber, and the decrease of such shade will increase the competition of the undergrowth with the rubber. The ideal of rubber culture does not require a roof of shade over the rubber trees nor a dense growth of bushes and vines under them. The roof should be of Castilla foliage, and the ground should be covered by a mulch of dead leaves and branches, which enrich the soil and assist in the retention of moisture.

CLEAN CULTURE WITH FOREST PROTECTION.

If, then, the requirements met by close planting be eliminated from the shade question there remains little beyond the fact that in districts in which the dry season is unduly long it may be unwise to shorten the period of growth by cultural methods which increase the daily exposure to too dry an atmosphere, as there can be no doubt that the clearing of large tracts of land will mean warmer and relatively drier air, and that the dryness of the air near the ground will be further increased by the wind, against which the forest will no longer afford protection. It might accordingly be good policy on large estates not to clear continuous tracts for planting, but to leave belts of forest to break the wind and keep the atmosphere moist. This method would be particularly convenient where the land is to be cleared by burning, since in a tropical forest the trees often grow with their branches interlaced or are bound together by large climbing vines or lianas, so that it is often much easier to clear an entire strip of forest than to leave individual trees standing at anything like regular intervals.

METHODS OF HANDLING CASTILLA SEEDS.

The thin-skinned seeds of Castilla, like those of so many other tropical plants, are adapted only for germinating on the moist soil of the forest. Instead of having a hardened shell for protection, there has developed only a fleshy pulp, which in nature helps them to remain moist until the rains begin. They are able to resist exposure to even a moderately dry atmosphere for only two or three weeks, and if packed together in any quantity they spoil even more promptly. The perishability of the seeds has been a considerable obstacle in the planting of Castilla, and especially in its introduction into foreign countries. The first shipment of 7,000 seeds secured by the government of British India from Panama in 1875 was a total loss, and the introduction was made by means of a few cuttings, carried around by way of England. Later the Kew Botanical Gardens sent rooted cuttings also to Liberia and to the Kamerun River settlements in West Africa, to Zanzibar, Mauritius, Java, and Singapore, as well as to Jamaica and Granada in the West Indies.[a] In 1880 the largest of the Ceylon trees was 17 inches

[a] W. Thistleton Dyer, Trans. Linnæan Soc., London, 2d ser., 2:214, 1885.

in circumference a yard from the ground, and in 1881 they flowered for the first time. The first flowers were all staminate, but a few seeds were produced in 1882, and these and their successors have furnished the basis of the experiments with Castilla in the East Indies. The relatively unfavorable results may be due, at least in part, to the fact that the Panama tree is different from that of Mexico and Guatemala, which was sent to the East Indies only in recent years, after better methods of packing the seeds had been learned.

The preservation of the seeds depends upon their being kept moist enough to remain alive and at the same time dry enough to discourage germination. Some advise washing the seeds; others leave the pulp adhering, but the latter course has the disadvantage of encouraging the growth of molds and bacteria, which readily penetrate the thin outer membranes and attack the embryo itself. Several packing materials, such as leaf mold, sand, and sawdust have been suggested, but the best is probably powdered charcoal, which does not decompose nor harbor organisms.

The following statements from some who have experimented with shipment of Castilla seeds may be of suggestive interest:

In Trinidad they are gathered when fully mature, washed, and slightly dried in the shade. They are then shipped in a sort of humus composed of fibers of rotten cocoanut husks and a little earth. This mixture must be somewhat moist. The seeds soon germinate in it and so remain for several weeks. Sowing must be done with great care on account of the long sprouts.

I also collected the mature seeds and washed them thoroughly, so that no trace of the fleshy red pulp remained on them. Then they were dried in the shade from twenty-four to forty-eight hours, and then mixed with sawdust and packed in small tin boxes 10 centimeters (4 inches) square and 3 centimeters (1.2 inches) deep. I dropped a few drops of water on the sawdust before closing the box. With this packing the seeds were sent to Berlin, and from there forwarded to Kamerun and East Africa, and 50 per cent of them were on arrival still good and in condition to germinate.[a]

A shipment of 2,000 Castilla seeds sent from Paris to Peradeniya, Ceylon, packed in leaf mold in four tin boxes, was opened in six weeks, to find 37 per cent still alive and the remainder destroyed by molds and bacteria. This made it evident that leaf mold was not a desirable medium and sterilized sand was suggested instead.[b]

The seeds were carefully cleaned of all pulp, and then dried slightly in the shade and packed in shallow tins with powdered charcoal slightly damp. By this method they commence to germinate in the tins. Care must be taken that the seeds do not touch each other, for if too many are packed together it will cause heating and the loss of the whole.[c]

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[a] Dr. Paul Preuss, Expedition nach Central- und Sud-Amerika, 1901, p. 383.

[b] Agric. Bul., Straits Settlements, **1**:580. Dec., 1902.

[c] Letter from Mr. W. S. Todd, Amherst, Lower Burma, to Mr. Edgar Brown, in charge of Seed Investigations, U. S. Department of Agriculture.

It was learned also that rubber seeds packed in charcoal and shipped from one of the plantations of the Isthmus of Tehuantepec to the East Indies had arrived in good condition after a journey of forty-five days.

SEED BEDS AND NURSERIES.

Whether it is better to plant the seeds where the trees are to stand or to sow them in nurseries from which the seedlings are to be subsequently transplanted is one of the many questions on which opinions differ, though the latter method commands a large majority of preferences. Of 26 plantations from which reports have recently been published by the India Rubber World, only 3 plant "at the stake" exclusively.

At La Zacualpa Mr. Harrison has tried planting in the permanent location, but finds that the very young seedlings are liable to be destroyed by insects and that they do not grow as well in partial shade as in the full sun. But instead of leaving the plants in the nursery for a year, transplanting begins when they are six weeks old, or when the plants are from 10 to 12 inches high, and continues to near the end of the rains, no nurseries being carried over the dry season. These are considerable deviations from the methods which have been described in previous publications on rubber culture, most of which advocate the shading of the nurseries and the postponement of transplanting till the seedlings are a year old. It is claimed at La Zacualpa that the small trees suffer less from transplanting and that they are larger at the end of two years than if they had remained in the nursery for a year.

The seed beds at La Zacualpa are made each year in a new place convenient of access to the tracts which are to be planted. While the nurseries are not shaded overhead, they are generally located in clearings in the forest, where they have considerable protection against dry wind. The drying out of the soil would doubtless be fatal to young seedlings, but if the soil and air are sufficiently moist the sun does not harm them.

The land used for nurseries is cleaned by burning, though this is not the case at La Zacualpa with the plantation proper. When older seedlings are transplanted it is customary, as with coffee, to cut the taproot down to 5 or 6 inches, rather than to plant it bruised or bent. If the soil is loose and fertile the seedlings are set in holes made with a pointed stake; elsewhere it is better to dig holes, as with coffee. Castilla is not a delicate plant, and will endure any reasonable treatment. The worst danger seems to be that with long-continued rain and deficient drainage the young plants will rot off, or they may be killed by drought if planted too near the end of the rainy season. For those which have not become sufficiently established before the coming of dry weather artificial shade may be provided. At La Zacualpa one

of the tracts which represented an experiment in open planting had each young seedling covered with a hood made of leaves of the manaca palm (Attalea).

PROPAGATION OF CASTILLA FROM CUTTINGS.

Under favorable conditions Castilla roots readily from cuttings. Between Pueblo Nuevo and Huitzla, along the road from Tapachula to La Zacualpa, there is a row of several trees planted as fence stakes, but at present flourishing in an entirely normal manner. That trees raised from cuttings are not stunted or otherwise abnormal is also shown by many other instances in the neighborhood of Tapachula. Indeed, this was the origin of the largest tree observed (Pl. IX). It measured 7 feet in circumference about 5 feet from the ground. It was about 33 feet to the first limb and the total height was estimated at 80 feet. The owners claim that it has yielded 6 pounds of rubber. It had apparently not been tapped as persistently as trees at La Zacualpa, perhaps because protected from "huleros" by standing close to a house. Milk flowed freely from a knife cut, and appeared to be rich in rubber. Natives claimed that an arroba (about 25 pounds) of rubber could be obtained from such a tree by the methods used by them in the forest. This tree was further notable in that it had apparently grown up in the open and without near neighbors.

The propagation of Castilla from cuttings has already been mentioned as the quickest method of bringing about the selective improvement of Castilla. It is not known that any plantations have been stocked with cuttings, presumably because in localities where they could have been obtained seedlings could be had more readily and in larger numbers. Indeed, wood suitable for cuttings does not exist in very large quantities even in a well-grown tree, because the false or temporary branches can not be used for this purpose. Like the lateral branches of some of the coniferous trees, they are unable to give rise to normal terminal buds, so that even if false branches could be rooted they would not produce normal trees. The failure of such experiments has been reported from British India.

Planters resident in regions in which wild rubber trees exist could try a useful experiment by planting in rows cuttings taken from different wild trees known to be above or below the average in productiveness. This would enable them to determine whether the differences of yield were due to the external conditions or to causes inherent in the trees themselves. The probability is that very appreciable individual differences of productiveness will be found, and that a distinct advantage can be secured by using cuttings of such trees for propagating purposes.

The fact that stakes 5 or 6 feet long and 2 or 3 inches through take root and grow when simply set in the ground shows that propagation

from cuttings will be easy. The larger the cutting the more promptly the tree may be expected to reach maturity. Probably also the mature wood will root better than the succulent young shoots, as with many other tropical trees.

CASTILLA AS A SHADE TREE.

The substitution of Castilla or other rubber-producing species for the unproductive shade trees commonly grown with coffee, cacao, and other tropical crops has been persistently advocated ever since the subject of rubber culture began to receive popular attention. The advantage of such a plan appears so obvious and certain that many experienced tropical agriculturists have been betrayed into direct and even emphatic statements for which the facts have unfortunately failed to provide a warrant. Indeed, it might be said that this phase of rubber culture affords the best illustration of the lack of definite knowledge which hinders practical progress.

In the first place, the shading of coffee and cacao is a subject upon which there is much popular misconception and difference of opinion, the planters of some regions shading heavily and those of others not at all, and explaining their methods by the most contradictory reasons.[a] It seems, however, that there is not the slightest reason to believe that either coffee or cacao is injured by standing in the sunlight or is in any way advantaged by having its leaves shaded, though in countries subject to a long dry season the shading of the ground and the retention of atmospheric humidity may be beneficial cultural measures. That Castilla is in no way adapted for serving these purposes is apparent as soon as it is known that wherever there is a distinct dry season the leaves fall off at exactly the time when they are most needed. It is true that they would still be of some service in covering the earth, but, on the other hand, the loss of the accustomed shade renders the atmosphere much drier and may be a distinct injury to the coffee.

Not only does Castilla thus lack the first qualification of a shade tree, but its cultural requirements and those of coffee are entirely at variance. Castilla seems likely to produce rubber in paying quantities only at low elevations, while the profitable cultivation of coffee is seldom considered possible at an altitude of less than 1,000 feet. In elevated continuously humid coffee districts the rubber trees will hold their leaves but will produce little or no rubber, while to choose an intermediate situation would be more likely to insure two failures than to double the chances of success.

It is reported that an extensive experiment is being made in Salvador with Castilla as a shade tree for Arabian coffee.[b] The altitude is

[a] These have been discussed in some detail in Bulletin No. 25, Division of Botany, U. S. Department of Agriculture, entitled "Shade in Coffee Culture."

[b] Der Tropenpflanzer, 6:542, October, 1902.

not stated, but since the Castilla at two years from planting is described as only 3 to 8 feet high the conditions can not be regarded as favorable.

The suggestion of Castilla for cacao shade is somewhat more rational, since both trees are natives of the same regions of low elevation. As noted elsewhere, rubber was first planted at Tapachula as shade for cacao, but the experiment did not appear promising from the standpoint of the cacao, and was abandoned. Some of the cacao trees still remain, but they have never been vigorous and produce very little. Other causes of failure may, of course, exist, but it seems certain that the close planting which is now favored would make a rubber plantation a very poor place for cacao, and there is every reason to believe that, while cacao may not be benefited by shade, it may be seriously injured by sudden exposure to the sun, as happens when the leaves of Castilla fall in the dry season.

A further difficulty in the use of Castilla as shade is that, in order to permit anything to grow under it, wide planting is necessary, and this usually means a spreading low growth for the rubber trees, generally considered undesirable, because it makes the extraction of rubber difficult if it does not actually decrease the yield. In German New Guinea, for example, Castilla has been planted 33 feet apart in alternation with cocoa palms as shade for Liberian coffee.[a] It would seem that all three trees must suffer under this arrangement, but it will be interesting to learn which is injured least.

Vanilla culture under Castilla has also been suggested and may be worthy of consideration, since it is held that a period of dryness and exposure to the sun is necessary for the proper ripening of the pods. To successfully combine two or three cultures is, however, a difficult matter, even when all are well known, but the supposed practicability of such combinations has rested on ignorance of important details.

Several years ago the culture of Castilla received a considerable impetus from the recommendation of Dr. Daniel Morris, now imperial commissioner of agriculture for the British West Indies, that Castilla be used as shade for coffee and cacao in British Honduras, and an estimated return was made of $5 per tree in eight or ten years or $125 per acre, to be repeated at intervals of five years.

According to Dr. Carl Sapper, a German scientist very familiar with Central America, this advice has been followed with disastrous results. He says:

> In fact, the developments thus far in the field of Castilloa culture show on the average very little in the way of favorable results. Particularly does it seem to have failed completely when it has been combined with other tree cultures in order to lessen the expenses of opening rubber plantations. Thus, on the advice of the well-known English botanist, D. Morris (then in Jamaica), rubber trees were planted for shade in the coffee plantation San Felipe, near El Cayo, in British Honduras, and the result

[a] Der Tropenpflanzer, 7:21, January, 1903.

was that these shade trees ruined the coffee, but did not on the other hand themselves develop normally because they were planted too close. In other places, as in Tabasco, in the Department of Pichucaleo, in Chiapas, and in Chamá (Department of Alta Verapaz, Guatemala) rubber trees were used for shade on cacao plantations; but the cacao planters tell me that ule trees impair the growth of the cacao and do further damage through the falling of the leaves, so that they would much prefer to be rid of these shade trees if that were practicable. In other instances, where the ule was planted by itself, too close an arrangement was chosen, so that the trees were impeded in development and are still after twelve years of existence mere tall, slender, unproductive poles, as at Los Amates, Department Izabal, Guatemala, with only four yards of space.[a]

It seems, however, that Dr. Morris has a favorable report regarding Castilla as a shade tree for cacao, both in British Honduras and in the West Indies, and his former advice was repeated before the agricultural conference of the West Indies in 1901. He said:

In 1883 I published an account of the Castilloa rubber tree of British Honduras and the manner of extracting and curing the rubber. At that time I recommended that these trees might be used as shade trees for cacao. A trial was made sixteen years ago, on a cacao plantation on the Settee River, and I learn from a letter from the superintendent of the botanic garden at Belize, dated November 8 last, that the rubber trees have answered admirably for this purpose. He writes: "At Kendal on the Settee River the cacao plantations are thriving well. * * * Castilloa was planted for shade; these are also in good condition; * * * there is not a better tree for that purpose." I am glad to find that similar results are reported from Trinidad and Tobago.[b]

The report from Tobago, to which Dr. Morris refers, is particularly enthusiastic and seems to indicate that under the conditions existing on that island the planting of Castilla with cacao may not be inadvisable:

I find that cacao bears very well under the shade of Castilloa. Nine years ago I planted an acre of rubber and cacao together—the rubbers at 24 feet apart, and the cacao 12 feet—and so far as I have noticed there is very little, if any, difference in the bearing of these cacao trees and those under the shade of the *Bois immortelle.* On finding this, I planted last year 15 acres in the same manner, and there is every reason to expect that in another eight or nine years they will give a gross return of about 50 pounds per acre. Coffee also bears well under *Castilloa.*[c]

The difference between Castilla and leguminous shade trees may become apparent in later years as the nitrogenous constituents of the soil become exhausted. As explained elsewhere, the question is not whether Castilla can be used as a shade tree, but whether it will be productive where it is of use in this capacity.

EXTRACTION OF THE LATEX OF CASTILLA.

Scarcely second in practical importance to a solution of cultural problems is the attainment of satisfactory methods of tapping. The

[a] Der Tropenpflanzer.
[b] West Indian Bulletin, 2:113, 1901.
[c] West Indian Bulletin, 2:111, 1901.

object is not merely to avoid the destruction of the trees, but to learn how the maximum quantity of rubber may be secured with the least injury to future productiveness. The planter needs to know how soon young rubber trees should be tapped, how the incisions should be made, how close together, how large, and in what direction; how often tapping may be repeated, at what seasons, and much more.

The first notion of the visitor from the United States is that it will be a very simple matter to improve on the rude gashes made by the machete of the rubber gatherer, but this has not proved to be easy. The rubber milk is not the sap of the tree and can not be drawn out by boring holes in the trunk, as is done with the sugar maple. The milk does not pervade the tissues of the tree, but is contained in delicate tubes running lengthwise in the inner layers of the bark, and to secure milk in any quantity it is necessary to open many of these tubes by wounding the bark. The rubber is formed in floating globules inside the tubes and can not pass through their walls, so that even a suction apparatus would not bring it out unless the tubes were cut.

PRIMITIVE METHODS OF TAPPING.

The method by which the natives of Soconusco have been accustomed to extract the milk is shown in Plate XVI. The ulero makes with his machete diagonal lines of gashes (Plates I and XII) that open channels along which the milk can flow until it is all brought to one side of the tree, whence it is led down to a cavity hollowed in the ground and lined with the tough leaves of Calathæa. These are dexterously lifted up, and the milk is poured out into a calabash or other vessel and carried away to be coagulated. The diagonal channels are from 2 to 3 feet apart, and those of each successive tapping are inserted between the older scars. The diagonal lines are carried well around the tree; to tap it on the other side requires much deeper cuts in order to pass the milk across the older grooves, down which it would otherwise run and be lost. That the trees at La Zacualpa had been able to survive so much of this barbarous treatment and were still vigorous and heavily laden with fruit seems to indicate great tenacity of life. And yet even this rough handling represents an improvement upon the former custom of cutting the trees down entirely or hewing steps in them for the ulero to climb up. Instead of the forked stick used as a ladder at La Zacualpa the large forest trees were ascended for 30 feet or more by means of ropes, vines, climbing irons, and steps cut in the trunk. The following is a description of a method of tapping the trees in the forests of Nicaragua:

> When the collectors find an untapped tree in the forest they first make a ladder out of the lianas or "vejucos" that hang from every tree. This they do by tying short pieces of wood across them with small lianas, many of which are as tough as cord. They then proceed to score the bark with cuts which extend nearly around the

tree, like the letter V, the point being downward. A cut like this is made about every 3 feet all the way up the trunk. The milk will all run out of the tree in about an hour after it is cut, and it is collected into a large tin bottle made flat on one side and furnished with straps to fasten onto a man's back. A decoction is made from a liana (*Calonyction speciosum*), and this, on being added to the milk in the proportion of 1 pint to the gallon, coagulates it to rubber, which is made into round, flat cakes. A large tree, 5 feet in diameter, will yield, when first cut, about 20 gallons of milk, each gallon of which makes 2½ pounds of rubber. I was told that the tree recovers from the wounds and may be cut again after the lapse of a few months; but several I saw were killed through the large harlequin beetle (*Acrocinus longimanus*) laying its eggs in the cuts, and the grubs that are hatched boring great holes all through the trunk. When these grubs are at work you can hear their rasping by standing at the bottom of the tree, and the wood dust thrown out of their burrows accumulates in heaps on the ground below.[a]

AGE AT WHICH PLANTED TREES MAY BE TAPPED.

The earliest age at which Castilla trees may be tapped with safety and advantage has been stated all the way from four to twelve years, while from eight to ten years is the conservative estimate. At the same time it must be admitted that little in the way of positive knowledge exists on this point, and careful experiments may be necessary to determine whether, for example, the taking of half a pound of rubber from each tree in the sixth year will retard growth so as to diminish the yield of succeeding years. As the trees approach maturity and have occupied most of the available space, as much may be taken as will not weaken the tree and shorten its life.

The inferior quality of the rubber obtained from young trees also lessens the inducement for tapping them. It has been known for several years that the rubber and gutta-percha obtained from young plants or from the leaves and twigs of the trees is different from that yielded by a trunk of mature age, in that a smaller or larger percentage of rubber is replaced by nonelastic, brittle, or sticky substances commonly referred to as "resins." Dr. C. O. Weber has recently published the following results of analyses of samples of rubber from trees varying in age from two to eight years:[b]

Resins in rubber from trees—	Per cent.
2 years old	42.33
3 years old	35.02
4 years old	26.47
5 years old	18.18
7 years old	11.59
8 years old	7.21

The same writer also gives a table showing the varying amount of resin in samples from different parts of the same tree:

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[a] The Naturalist in Nicaragua, Thomas Belt, F. G. S., pp. 33–34. The liana called by Belt *Calonyction speciosum* is generally called *Ipomoea bona-nox*.

[b] Tropical Agriculturist, **22**:444, January, 1903.

Resin in rubber from—	Per cent.
Trunk	2.61
Largest branches	3.77
Medium branches	4.88
Young branches	5.86
Leaves	7.50

If these figures represent facts at all general, they lessen very distinctly the prospects of any plans which contemplate the tapping of very young trees, and it will be necessary to agree with Dr. Weber that eight years is the minimum age at which a plantation can be expected to furnish rubber for the market.

But as this point is one which has been brought into considerable prominence in recent years, and is being relied upon by some as a means by which the profits of rubber culture can be increased and hastened, it may be well to state that the inferiority of the rubber of young trees and growing parts has been determined by other competent investigators and especially by Mr. Parkin, whose account of the matter furnishes several interesting details which supplement the figures furnished by Dr. Weber:

In the case of Hevea, the rubber collected from the young stems and leaves, as well as from the unripe capsules, is somewhat adhesive, and has less elasticity and strength than that from the trunk. In the Castilla introduced into Ceylon the latex from the stems bearing leaves, as well as from the leaves themselves, molds between the finger and thumb into a very sticky substance, wholly unlike the caoutchouc-containing latex of the trunk. It dries to a brittle material, which becomes viscous when warmed. The quality of the rubber from stems of this Castilla, 12.5 to 25 centimeters (5 to 10 inches) in circumference, was likewise tested. It seemed to have properties intermediate between that of the shoots and the trunk, being slightly sticky and somewhat deficient in elasticity.

The climbing rubber plants, *Landolphia kirkii* and *Urceola esculenta*, show a similar difference between the latex from the shoot and that from thick stems. *Ficus elastica* also exhibits this peculiarity.[a]

Attention was called to this in Ficus as far back as 1839 by Weinlung. He called the substance "viscin," and considered it intermediate between resin and caoutchouc.

Mr. Parkin further says:

In many plants this so-called viscin seems to occur throughout the laticiferous system, e. g., the common bread-fruit (*Artocarpus incisa*) and jak (*A. integrifolia*), trees of the Tropics.

Most likely there are bodies which do not come within the categories of caoutchoucs and guttas, and yet are hydrocarbons with the same percentage composition. Probably some of these viscous substances are such. Also it appears probable that all caoutchoucs are not identical, and that when prepared as pure as possible from the latex, as by the ingenious centrifugal method of Biffen, it may be found, for example, that the caoutchouc of Hevea has slightly different properties from that of Castilla.[b]

[a] See Weiss, Trans. Linn. Soc., 111, 1892, p. 243.

[b] Parkin, Annals of Botany, **14**: 203-204, 1900.

DIRECTION AND SHAPE OF INCISIONS.

The tubes which produce the milk of Castilla and other rubber trees are so slender and thread-like that the creamy liquid would not flow from their cut ends if it were not forced out by pressure. Some writers seem to have assumed that the liquid is actually compressed inside the tubes, or that the walls of the tubes are stretched by the liquid they take up. A more probable view is that recently advocated by M. Lecomte,[a] that the pressure is due to the tension of the bark, and that it is mostly exerted in a transverse direction. If we add to this the fact that nearly all the tubes extend lengthwise, a transverse cut would reach the maximum number of these and would thus for two important reasons secure more milk than one of the same length in any other direction. A cut along the trunk would be the worst, since it would reach the fewest tubes and relieve the tension of the bark most. Oblique cuts are intermediate, the more horizontal the better. M. Lecomte hesitates to recommend transverse cuts lest they may prove injurious to the tree; but if a short transverse cut will bring as much milk as a longer oblique gash there seems to be no real reason why it should be more harmful, providing, of course, the tree be not girdled, or too much bark be not cut away at one level. The practical difficulty with transverse cuts lies in the fact that it would be much more difficult to collect the milk, some of which will stay in the cuts, while the surplus will run down the trunk of the tree in many driblets instead of being brought together at the point of the V-shaped incisions generally used. The desirability of making the cuts as nearly transverse as possible should, however, be considered, and in districts where, as in eastern Guatemala, dependence is placed entirely on the "scrap" rubber, most of which coagulates in the cuts or on the surface of the trunk of the tree, it may be feasible to make the cuts nearly or quite transverse. Indeed, this is what Dr. Preuss describes as customary on the El Baul plantation in Guatemala:

> For tapping they use an instrument made out of a bush knife (machete). The end of the blade is for this purpose bent back until a groove is formed about broad enough to lay a finger in. The cutting edge of this groove is well sharpened. With this instrument the workmen tear *horizontal* gashes in the bark of the trees, and indeed over a half or three-quarters of the circumference of the trunk. The grooves are cut at distances of 1½ feet, one above another, up to the principal branches. The milk at first flows out in drops, which fall to the ground. They let these go to waste because the quantity is only small and this milk is very watery. But in a minute or two the dropping ceases and the milk which then oozes out is pulpy and remains in the furrows, where it hardens into strips of rubber. In two days these strips are pulled out, washed, and dried in the shade, and are then ready for market. Drying in the sun causes the rubber to become sticky and should be strictly avoided. The trees are tapped four times a year; each time another side of the trunk is operated

[a] Journ. d'Agri. Tropicale, **10:** 100. Translated in Agriculture Bul. Straits and Federated Malay States, **1:** 382.

on. The yield each time is half a pound of rubber, or one kilogram (2.2 pounds) in a year. I was informed that the horizontal grooves made with the instrument described require only a quarter as much time to fill up as the broad diagonal wounds made with the machete. The former are completely closed in three months' time, and the tree recovers very rapidly.

Parkin's experiments in tapping Hevea in Ceylon gave results much in favor of oblique incisions over either horizontal or vertical. He says:

> In both cases the oblique incision yields about double that of the other. There seems little difference between the amount collectible from a vertical and a horizontal incision. Although there is a greater output of latex from the horizontal cut, yet much more dries on the wound than in the case of the vertical, consequently the amount which drops into the receiver comes to about the same in the two cases.[a]

With Hevea it was found that two oblique incisions joined below to make a letter V gave nearly twice as much latex as one alone. In case of Castilla, however, where the milk flows so much more freely, it was concluded that the most milk could be secured with the least injury to the tree by means of separate oblique incisions. Such cuts would certainly heal more readily than V-shaped wounds, since the bark frequently receives its worst injuries at the junction of the two incisions.

TAPPING INSTRUMENTS.

That improved methods and tools are to be used for cultivated trees is one of the points on which all the rubber planters agree, but as yet none of the many improvements suggested has attained any popularity, and it is at least doubtful whether any of the devices brought forward at this time is to be looked upon as a practical solution of the problem. Some inventors have worked on the erroneous idea that the rubber comes from the sap, like sugar from the maple, and have thus completely wasted their time.

An enumeration of some of the features essential for a good tapping instrument may save further labor on wrong lines.

The cutting edge must be keen, and must therefore be easy to sharpen. A thick or blunt edge bruises the wood and milk tubes, and this interferes with the flow of milk.

There should be a means by which the depth of the cut can be regulated, since it is important to cut deep enough to reach the milk and yet not so deep as to reach into the wood, but axes and chisels with shoulders to prevent too deep penetration are not promising because the thickness of the outer bark is variable. The shoulders also bruise the bark if the cutting is by blows. In British India it is thought that the best instrument for tapping the Para rubber trees is an ordinary carpenter's gouge.

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[a] Circular Royal Botanic Gardens, Ceylon, June, 1899, p. 121.

MULTIPLE TAPPING.

By far the most important recent discovery in connection with the culture of Para rubber in the East Indies is what may be called multiple tapping, or the repeated cutting of the edges of the wound to induce a renewed flow of milk. This is, it is true, by no means a new idea, since it seems to have been the regular practice of the rubber gatherers of Brazil; but their idea that the tree gave more milk after it had become accustomed to the operation seemed so childishly fanciful to Europeans that it has only recently been put to a practical test, and now there is much surprise to find that it is very decidedly correct. Perhaps the most striking instance is that described very recently from Selangor, where a single Para rubber tree 25 years old yielded 18 pounds of rubber in a period of two months.[a] A single ounce was obtained the first day, and 1½ pounds in the next five days. For 10 days the daily average was more than half a pound, and on the twelfth day a maximum of 12 ounces was obtained. A second tree yielded a total of 12 pounds 10 ounces of rubber. It was estimated that about seventy hours of labor was required to collect about 30 pounds of rubber from the two trees, or over two hours for each pound of rubber, which may be noted as an indication that the collection of rubber by this method will be expensive in proportion as it is carefully done, since it will require intelligent and somewhat skillful cutting to avoid too serious injury to the trees.

PROTECTION AGAINST THIEVES.

A serious obstacle to profitable rubber culture in some parts of Central America is the stealing of the milk by the natives, and especially by those who have been accustomed to make a living from the tapping of the wild trees. Trouble from this source is likely to be much worse in countries where rubber is a natural product than in regions where the natives have not been accustomed to gather and sell it, and where no recognized trade exists to make easy the marketing of the contraband product. According to Dr. Carl Sapper,[b] long a resident of Central America and widely acquainted with social and agricultural conditions, many landowners have given up rubber culture because they find themselves unable to guard their trees from thieves who do not even wait to rob them of their crop, but destroy the young trees as soon as they begin to produce. A similar report is current from the banana-growing districts of the eastern seaboard of Central America, where experiments in rubber culture are said to have been given up not because the trees failed to grow but because

[a] Agricultural Bulletin of the Straits and Federated Malay States, 1:556, November, 1902.

[b] Der Tropenpflanzer, 3:585, 1899.

the planters found that they would be unable to harvest their crop. In the West Indies and in many other tropical countries it has been found difficult to grow fruits and other food crops in proximity to a lawless native population, but rubber is even more difficult to protect, because of its high value, its continued presence in the tree, the ease with which it can be taken, the long time it can be stored, its small bulk, and the facility with which it can be transported and marketed.

These facts will increase the hazard of many rubber investments and will render obvious the advantage of enterprises operated in settled communities and protected by stable and responsible governments, for in the waiting period of eight or ten years many vicissitudes may be encountered. The ease and profit with which a rubber plantation could be plundered would be equaled only by the havoc which would result from reckless depredation.

To meet ordinary needs of protection two expedients may be suggested. In countries which are anxious to encourage the preservation and planting of rubber others than landowners and planters could be prohibited from marketing crude rubber or from having it in their possession, merchants being compelled to account for their exports by purchase from such authorized persons. On the other hand, the use by planters of special tapping tools not obtainable by the natives would make it possible to detect the theft of rubber, which is now extremely difficult. Indeed, the estates are often robbed by their own employees, and the rubber sold from "our own trees" by some of the companies is said to be purchased from thieves who save the owners the trouble of gathering their rubber.

The problem of rubber gathering is thus a real one which should be attacked with vigor and persistence. Not only are the present Central American methods quite unsuitable for use with cultivated trees, but there is a scarcity, and in many districts a complete absence, of laborers capable of applying even the present barbarous treatment. If their cultural efforts should prove successful it will be but a few years when plantation managers who have set out trees by the hundreds of thousands may find themselves unable to extract the liquid wealth. The temptation will then be great to end the tedious waiting for results by turning the plantations over to the mercies of the "huleros," if, indeed, it be found practicable to prevent them from helping themselves.

METHODS OF COAGULATING THE LATEX OF CASTILLA.

COAGULATION BY CREAMING.

The separation of rubber from the latex, a process commonly called coagulation, is in a somewhat more advanced state of investigation than the subject of tapping, if, indeed, the recent experiments of

Dr. Weber do not mean that a final and satisfactory conclusion has been reached. Dr. Weber finds that by the simple expedient of diluting the fresh latex of Castilla with five times its volume of boiling water and adding 8 ounces of formaldehyde to each barrel of the resulting fluid, all the impurities to which the inferiority of Castilla rubber are due can be removed, since they will remain in solution, while after twenty-four hours the clean rubber will be found in a "snow-white cake" which can be lifted off the top. Dr. Weber contends that rubber prepared in this way is "absolutely free from solid impurities of any description, * * * either soluble or insoluble, organic or inorganic," and that it is equal or superior to the finest brands of Para rubber. The process is simple and inexpensive, and if the mechanical qualities of the rubber meet Dr. Weber's expectations when the practical tests of manufacturing have been applied, it would seem that the essential requirements of the problem have been met, and in any case valuable progress has been made. It seems, moreover, from the investigations made by Parkin in Ceylon that this method is capable of still further simplification.

When the latex of Castilla is mixed with water and allowed to stand, in the course of an hour or two the caoutchouc particles have all floated to the top in the form of a thick cream. The diluted latex of Hevea, on the contrary, shows no signs of creaming, even when submitted to a low temperature. The difference is most likely due to the larger size of the caoutchouc globule in the case of Castilla as compared with that of Hevea.[a]

Parkin found, however, an interesting difference between the latex of Castilla in Ceylon and that described from tropical America by Biffen, in whose results Weber may be said to acquiesce, since he holds that the albumens of Castilla latex are readily coagulated by alkaline solutions.

The proteid of the latex of *Castilla elastica* has also been investigated to some extent by Biffen. He found that the latex gives an acid reaction, and that on the addition of a little alkali it is coagulated. This he considered to be due to the nature of the proteid which exists as acid albumen in the latex; on neutralization it comes out of solution and gathers together the caoutchouc particles into clots.

Now, the latex of the Castilla introduced into Ceylon (*C. markhamiana*) does not behave like this. On the very gradual addition of alkali to the latex or to the filtrate (the liquid part of the latex without the globules of caoutchouc) no coagulation or precipitation occurs. Alcohol causes a coagulation of the latex and a copious precipitate in the filtrate, which is quite soluble again in water. Proteid is present in considerable quantity, about 4 per cent being indicated by analysis. Coagulation is brought about neither by acids nor by boiling. Thus it looks as if the proteid belongs to the class of albumoses. At any rate the type of Castilloa introduced into Ceylon differs in this respect strikingly from that of the true *Castilloa elastica* examined by Biffen.

These facts are of interest, not only from their bearing upon coagulation and function of latex, but because they indicate the extent to

[a] Parkin, Annals of Botany, 14:198, 1900.

which the latex and its constituents may vary under different conditions of growth. Parkin is probably in error in the idea that the latex with which he experimented belonged to *Castilla markhamiana*. The tree which was introduced by Cross from Panama to Ceylon is more likely to be the same as that with which Weber experimented in Colombia.

DISCOLORATION OF CASTILLA LATEX.

Incidental to his principal discovery Dr. Weber reports several observations of much interest, not alone in their practical significance, but also as illustrations of the mistakes which can be made in a subject so difficult of investigation as rubber. Thus it is found that the milk of Castilla contains not a trace of tannic acid, the presence of which has often been inferred, presumably because ferric chlorid produces the same color reaction with latex as with tannic acid, turning it dark green. This reaction Dr. Weber finds to be due to the presence of a glucoside, which also gives the latex its intensely bitter taste. The addition of tannic acid precipitates the albumens of the latex, so that the presence of albumens is itself deemed a sufficient evidence of the absence of tannic acid in latex of any kind.

The rapid color change of the milk of Castilla on exposure to the air is found to be due to an enzym or oxydizing ferment (oxydase), which is probably destroyed by the boiling water, as suggested by Parkin, to whose work Dr. Weber does not refer, although in this part of the subject it had covered the same ground.

Parkin reported as follows:

> Several latices, which are pure white when they first issue from a wound on the plant, rapidly darken on exposure to the air. This is due to the presence of an oxydizing ferment, or oxydase, which with the aid of the oxygen of the air acts on some constituent of the latex, changing it to a deep brown coloring matter.
>
> The latex of Castilloa is a good example. It rapidly darkens on exposure and dries to an almost black rubber. By creaming the caoutchouc particles can be separated from the dark beer-like liquid and made into a sheet of nearly colorless rubber. By quickly heating the collected latex the darkening is arrested, owing to the destruction of the enzyme.
>
> The latex of Hevea collected from the tree trunk does not darken at all on exposure to the air, and, provided that molds and putrefactive organisms are kept away, rubber prepared from it remains indefinitely of a light color. On the other hand, the latex from the wall of the unripe capsule (fruit) changes on exposure from milk-white to black. The darkening is wholly prevented if the latex is quickly subjected to heat. No doubt there is an oxydase present in the latex of the capsule.[a]

The expression "coagulation of rubber" appears objectionable to Dr. Weber because he finds that it is the albuminous substances of the latex which coagulate and not the rubber itself, but this objection seems rather overtechnical, since, even in Dr. Weber's method, the rubber is collected and compacted, and for this process a name is still

[a] Parkin, Annals of Botany, **14**: 199–200, 1900.

required. It is the albuminous substances incorporated in Castilla rubber which continue to ferment and putrefy, or otherwise contribute to the deterioration of the rubber, both crude and manufactured. In other words, it is the albumens rather than the resins which determine the inferiority of rubber, and the amount of resin contained in the latex of adult Castilla trees is held to be "entirely innocuous" and "absolutely unobjectionable." Dr. Weber continues:

> I am quite aware that now and then all sorts of sinister actions are ascribed to the presence of resins in india rubber, but there is not the least particle of evidence to show that they are intrinsically detrimental. As a matter of fact, in the manufacture of quite a number of rubber goods, resins are deliberately added to the mixings.[a]

OTHER METHODS OF COAGULATION.

The traditional method of treating Para rubber in Brazil is to spread it in thin layers on wooden paddles, which are held over burning palm nuts. The highest grades of commercial rubber have been produced in this way, but the process is too slow, laborious, and disagreeable. There seems, however, to be ground for a suspicion that some constituent of the smoke, which is incorporated into the rubber, may have a beneficial effect upon its mechanical properties, and the previously cited adverse opinion upon the pure but unsmoked Hevea rubber from the East Indies seems to give further warrant for such a notion. The experiment of smoking Castilla rubber has been tried at La Zacualpa, but the result was a hopelessly sticky mass. The difference of behavior is, however, more likely to be due to differences in the latex rather than to differences in the rubber itself.

It is not to be overlooked that, while the high percentage of albuminous impurities in Castilla rubber has rendered the price lower and the removal of them should increase the price, yet it will reduce the quantity of the marketable product and will thus not be an unmixed advantage. All the methods of coagulation now in use bring about the incorporation with the rubber of a large amount of the albuminous substances of the latex. Dr. Weber claims that if none of the albumens are left out they will constitute over 25 per cent of the solid product and adds:

> The native rubber collectors prepare the rubber from the latex in such a way that at least part of the aqueous vehicle of the latex is drained away before coagulation takes place, and consequently we never find a Central American rubber (crude) which contains as much as the above-stated quantity (25 per cent of albuminous matter), but lots containing from 9 to 13 per cent are quite common.[b]

The meaning of this sentence is not obvious, and it becomes still less so if we read it in connection with one which follows a little later.

> Therefore, whenever we coagulate the rubber, we can only do so by coagulating it in conjunction with the albumen present, and we have at once a product possessing all the irremediable drawbacks which above we discussed at some length.

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[a] Tropical Agriculturist, **22**:444, January, 1903.

[b] Tropical Agriculturist, **22**:442, January, 1903.

None of the native methods of coagulation enumerated by Dr. Weber shows any provision for eliminating any part of the albumen. There is certainly nothing of this kind in connection with scrap rubber, into which all the solid constituents of the milk are simply dried down and little escapes except by evaporation, and yet scrap rubber is commonly deemed of good quality. In coagulation by the acid or alkaline juices of plants or by soap, salt, or alum, or by the boiling of the juice, the only materials which escape are those which do not coagulate, so that it is difficult to avoid the inference that the percentage of albuminous matter is not constant or that it has been incorrectly determined.

At La Zacualpa was witnessed still another method of coagulation by which all the nonvolatile constituents of the latex are retained. The latex is spread in a thin coating upon the large banana-like leaves of a species of Calathæa, laid out on the hot bare ground in the open sun. This exposure to heat, light, and air turns the milk dark with great rapidity, and in a few minutes it has become firm enough to permit a second layer to be spread on. Subsequently two of the leaves have their rubber-covered faces pressed together by being trodden upon, and the rubber adheres to form a single leaf-like sheet from which the leaves themselves are easily stripped away. Three stages of the process and the finished product are illustrated in Plate XVII.

COAGULATION OF SCRAP RUBBER.

Whether due to a varietal difference in the trees or to climatic or other differences of the external conditions, it seems to be a general fact that on the more continuously humid eastern slope of Central America the milk of Castilla does not run from the trees in quantities which can be collected and treated by improved methods of coagulation, but hardens in the cuts made by the rubber gatherer, who does not carry home the milk but returns in a day or two to pull out the dried "scraps," as rubber obtained in this way is called in the trade. As both the quality and the price of scrap rubber are satisfactory, the chief objection to this method of harvesting is the greater number of cuts in the tree and the greater amount of labor necessary to collect it, though the latter objection is somewhat counterbalanced by avoiding the work of coagulation. The principal point is the amount obtainable, and this depends upon the question of climates and varieties rather than upon that of coagulation. According to Professor H. Pittier, 6 pounds of scrap rubber are sometimes taken from a single wild tree in Costa Rica; but while this amount is considerable it is much less than that claimed by Koschny for the same country.

PRODUCTIVENESS OF CASTILLA.

YIELD OF WILD TREES.

That the Central American rubber tree, or at least some of its species or varieties, may attain a very large size in nature and may yield a very large amount of rubber, there is abundant testimony. Such facts have, however, only secondary interest from the cultural standpoint, because there are no means of determining the age of such trees. It has been claimed that as much as a hundred pounds of rubber has been obtained from a single tree. Koschny relates that in Costa Rica in the earlier days giant rubber trees 10 to 13 and even 14 feet in circumference were commonly found. All such have been destroyed by the rubber gatherers. Nothing but second-growth and young trees are now to be found.

The early literature of rubber culture abounds in statements exceeding the fondest dreams which the modern stock company dares to put on paper. We may be certain, for example, that rubber culture would not be still a new industry in Central America if the planters of that region had found facts to warrant the statement published by Collins in 1872, which probably led to the introduction of Castilla into British India.

> A tree of about 18 inches in diameter bled by skillful hands in April would yield about 20 gallons of milk capable of giving 50 pounds of caoutchouc. This is, however, the maximum yield; the average is a little below this. A tree of from 20 to 30 feet to its first branches is expected to yield 20 gallons of milk, and each gallon of milk to give 2 pounds or 2 pounds 2 ounces of good dried rubber. [a]

This estimate was somewhat reduced by Mr. Cross who visited Panama in 1875 to procure Castilla for India. He says:

> A Castilla tree, with a diameter of 1½ to 2 feet, if carefully and judiciously tapped, may be expected to yield about 12 pounds of rubber per annum. Of all the different species of rubber-producing trees, the *Castilla* should prove, under cultivation, the most remunerative. [b]

YIELD OF CULTIVATED TREES.

Two questions must be considered in attempting to judge of the value of reported yields of rubber from planted trees. One is the direct issue of veracity, the other the possibility of errors in some one or more of the many known and unknown ways in which these can come about. There can be no doubt that many direct and intentional misrepresentations have been published regarding rubber culture, and it would be quite gratuitous to suppose that those whose testimony on other points is obviously wrong have been more careful when discussing the subject of yield. Until it can be shown that somebody has had

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[a] Report on Caoutchouc of Commerce, p. 15.

[b] Report on the Progress and Condition of the Royal Gardens at Kew during the Year 1881, p. 13.

a motive for reporting yields as smaller than they actually were the average reliability of small yields must be taken to be greater than that of large ones, though not, of course, establishing the falsity of higher figures. To the writer, at least, it appears significant that not one of the reported large yields from planted trees of Castilla has been supported by the testimony of a disinterested witness of scientific standing or even of wide reputation in other lines. Moreover, it seems necessary to attach much importance to the fact that among many planters and other residents of Guatemala and southern Mexico, all more or less directly interested in the possibilities of rubber culture, none was found who had witnessed or who credited the higher figures, but many denounced them as misrepresentations injurious to the legitimate development of rubber culture.

An exceptional yield is still an exceptional yield, and not an average which can be used as the basis of general calculation of the profits of rubber culture. To be brief and explicit on this point it may be said that at the present stage of this inquiry 2 pounds per tree is looked upon as the reasonable maximum yield to be expected from adult trees of twelve years and upward, growing under favorable natural conditions. This is the highest estimate which is known to the writer as having been made by reliable planters of intelligence and experience; and some such hold that the probabilities lie nearer to half a pound than to 2 pounds. It is appreciated that this estimate is much smaller than many claims based on wild trees, and that it is much larger than the results reached on some of the earlier plantations would seem to promise. The estimate is not, however, made as an average of all published figures, but is reached rather by the elimination of unwarranted expectations from one end of the series, and from the other of disappointments due to adverse local conditions.

The writer's only opportunity of witnessing the extraction of rubber except by small knife cuts was at La Zacualpa, where two of the 14-year old planted trees were tapped for his benefit (Pls. XVI and XVII). This was about the first of May, at the end of the long dry season, an unfavorable time for such an experiment. The result was slightly over a pound of rubber, coagulated, and dried on Calathaea leaves as previously described; but no reasons were apparent for doubting the claim of the management that 2 pounds of rubber had been secured at one time from neighboring trees of similar size and equal age, The trees tapped were about a foot in diameter at 3 feet from the ground, and as shown by the plates, they had been tapped severely and repeatedly. On the same occasion an ulero brought in about 10 pounds of milk, from which 6 pounds of fresh rubber was obtained by coagulation with the juice of Ipomœa; the same pad of rubber weighs about half as much after a year's drying.

Koschny, whose paper on the culture of Castilla has been accepted

in Europe as the most authoritative work on the subject, states that vigorous 8-year-old trees will yield without injury something over a pound of rubber from three tappings, but he gives no intimation that this represents an average of any considerable number of planted trees, and, while he claims that his rubber gatherers have secured as high as 3¾ pounds from wild trees eight or nine years old, the uncertainty in the age of wild trees prevents such figures being relied upon, as he himself admits in another place.

This uncertainty of the time factor greatly reduces the value of figures derived from wild trees, particularly if complicated with other variable elements. The quality of rubber is known to differ with the age of the tree, and the same may be true of the quantity. The size of a forest-grown tree is no indication of its age as compared with one grown in the open. Wild trees are subjected also to an amount of cutting which nobody would advocate for planted trees. If the trees at La Zacualpa had been ascended with ladders and the whole trunk tapped, twice as much rubber or more might perhaps have been secured, or say 4 or 5 pounds at a more favorable season, but such an extension of the wounds of the trunk might be too much for even the persistent vitality of Castilla in Soconusco.

The planted trees at La Zacualpa abundantly demonstrate the practicability of rubber culture, but they leave the question of yield quite in doubt, for during a period of several years the experiment was abandoned, or at least entirely neglected, by the former owners of the estate and the trees were left at the mercy of the local uleros, so that it is now as impossible to learn how much rubber has been taken from them as to know how large and how productive they would have been had they been protected while young and tapped only with care and moderation.

It will be several years before adequate information on the yield of planted Castilla trees can be had, because, even after the trees have reached a productive maturity of eight years, an equal or longer period may be needed for experiments with different methods and times of tapping, before it will be known how the most rubber can be taken out with the least injury to the trees.

PROFITS AND PROSPECTS OF CASTILLA CULTURE.

MANAGEMENT OF RUBBER PLANTATIONS.

The extent and character of the correspondence received by the Department of Agriculture during the last two years show that many readers will expect rubber culture to be discussed not alone from the standpoint of the planter, but from that of the investor as well. It does not follow that any agricultural industry which may be profitable for the individual planter will be equally advantageous for one who

supplies only capital and has no personal oversight of his property. When business of any kind can be systematized and conducted on a large scale the duplication of many expenses can be avoided and the profits increased proportionally, but this is obviously not true to the same extent for all industries. A sugar plantation, for example, must have a factory with expensive machines, skilled workmen, and competent management. The output can be doubled or much further increased with relatively little additional expense; consequently the consolidation of sugar estates and the abandonment of small plantations has gone forward with great rapidity in the last decade. To open a modern sugar estate large enough to be economically conducted costs from $300,000 to $500,000 and many are still larger. The water supply, tanks, machinery, and buildings required on a properly conducted coffee plantation cost from $50,000 to $100,000 or more, or enough to give large estates a decided advantage in economy of production, though far less than in the case of sugar. Unless it be where irrigation works are also required, it is not claimed with sugar that, in the plantation proper, the very large estates are superior to those of small size; and where the small grower can sell his cane at fair prices at the factory he is not obliged to go out of business. Coffee, also, is still produced extensively on small estates, and, if cooperative "beneficios," or cleaning and curing establishments, existed, the berries could be produced as profitably in proportion on 100-acre farms as on estates of 5,000 acres.

This digression may, perhaps, be pardoned if it helps to make plain the fact that rubber companies owe their existence not to any obvious advantage which they will enjoy in competition with the individual planter, but to estimates of exceptional profits which have attracted the nonresident investor. The manufacturing side of rubber culture, the labor of preparing the product for market, is relatively smaller than with almost any other crop, and the need of centralization is correspondingly less. It is to be expected that processes and appliances for washing, separating, and coagulating the rubber will be introduced, but there is little indication that these will be very complicated or very expensive of installation. The profits of rubber culture will depend primarily on the selection of proper locations, economical methods of culture, effective management of field labor, careful tapping, and watchfulness against thieves. All of these things the individual planter can attend to as well or better than the large concern. To coagulate, cure, ship, and market the rubber will also be necessary, of course, but the outlay for these will be comparatively small. If rubber culture is to be highly profitable for stock companies it will not be less so for the small landowner. Indeed, it would be difficult to mention another crop which, from the cultural standpoint, appears so preeminently adapted for the individual planter and

for remote localities where the carrying in of heavy machinery and the bringing out of bulky products would destroy the profits.

Unless combined with other crops, the long period of waiting tends to make rubber planting difficult and unpopular for individuals with small capital; but the same delay also increases the risk of larger enterprises because the productive resources of an estate remain longer in uncertainty, and the proof of the ability and efficiency of the field management must be deferred. In other industries, like coffee and sugar, such facts come much more quickly to the surface. This objection is somewhat counterbalanced by the fact that the capital required to plant, cultivate, and harvest a given area in rubber is less than with most other crops. Nevertheless, until rubber culture has emerged somewhat from the experimental stage its greatest expansion should be expected to take place not in new regions, but as an adjunct to industries already established. This is preeminently true of the recently developed rubber industry of the British East Indies, and it is in the same way that rubber culture is first to be encouraged in Porto Rico, Hawaii, and the Philippines. Experimental plantings by residents of all promising regions can be made with little expense to individuals, and with little danger of loss on large investments. Landowners will wish to know whether their estates will produce rubber, and will be repaid for their trouble by having seed available for further planting as soon as their trees reach maturity.

SECURITY OF INVESTMENTS IN RUBBER PLANTATIONS.

The possibility of large returns is a powerful attraction to investors, and often renders them blind to the equal or greater possibility of loss. The difficulties attendant upon the development of a new industry are seldom attacked until somebody has been persuaded that it will yield a fortune more easily than older lines of activity. The difficulties are, however, commonly much greater than at first anticipated, and, although persistence may finally justify the effort, the first estimates have to be revised in the light of practical experience. As already explained, not all rubber trees yield even 2 pounds of rubber; the trees will thrive where they will not produce rubber; climatic conditions are uncertain; labor is not always available; the cost of collecting cultivated rubber will probably be greater than for the wild rubber; quality and prices vary; managers may be incompetent or dishonest; and many other circumstances may conspire to prevent the realization of the investor's hopes. The large profits calculated from rubber culture on theoretical grounds have not prevented some estates from proving a total loss, and do not render rubber culture a more secure field of investment than other agricultural enterprises. A large margin of normal profits may lessen the danger of actual loss

in an established industry, though it does not render the income permanent, but prosperity is very liable to invite competition. It is true that with rubber the decline of prices from this cause is likely to be a remote danger, but the more brilliant the success of the industry the greater would be the certainty of the extensive participation of all suitable regions.

To pick up from the surface of the ground large-sized nuggets of gold is very profitable, but to operate gold mines is often a losing venture. The ore may fall below the estimated richness, the mines may be difficult to drain, the machinery may be unexpectedly expensive, the wages may advance, or the management may prove dishonest. A rubber plantation yielding perpetually an abundance of high-grade rubber might be "as good as a gold mine," but investors must expect that the profits of plantations will be subject to vicissitudes. It may be legitimate to represent the profits of a certain rubber enterprise as more sure than its competitors in the same or other lines of investment, but those who claim that rubber enjoys any special or unique security either deceive themselves or wish to deceive others. The expenses for land, equipment, culture, and management will vary; likewise the yield, quality, and market price. If the margin of possible profit be larger than in older agricultural industries, the universal lack of experience makes it the more difficult and uncertain of realization. Moreever, the demonstration that rubber culture is really a highly profitable business would attract so many aspirants to fortune that the anticipated rise in the price of rubber might never be realized; and, although there is not likely to be danger of overproduction for many years to come, the "perpetual dividends" sometimes advertised can scarcely be insured. Finally, the artificial production of rubber is a distinct possibility, pursued by the chemists with eagerness and confidence, and the discovery of such a process might completely change the prospects of an investment in rubber culture.

The careless confusion of the milk or latex with the sap is responsible for many of the misleading representations that the profits of rubber culture are sure. Even the sending of stockholders or disinterested parties to count the thrifty young trees on the plantations does not insure the anticipated returns, since, as already explained, the growth of the tree either in nature or in cultivation does not certify the production of paying quantities of rubber. That rubber planting is as sure as raising wheat, apples, or strawberries, or keeping a dairy, are misleading statements, to say the least.

Even if rubber came, like sugar, from the sap of the tree, it would not follow that the yield would be uniform either in quantity or quality. Different varieties of canes and beets vary greatly in this respect, to say nothing of the influence of soils and climatic conditions. With older farming industries these elements of success or failure are known

and reckoned with, but the rubber industry has only commenced the accumulation of experience.

Neither should it be deemed a sufficient guaranty of the success of a plantation, or even of the good faith of a company, that prominent names should be found among the shareholders or officers. Rubber planting is so far out of the range of ordinary business ventures that men who would be trustworthy guides on investments at home are by no means proof against the miscalculations which have disappointed experienced tropical agriculturists; and it is not to be expected that all rubber companies will be found exempt from the well-known plan of securing indorsement by presents of stock and other less direct considerations by which apparently responsible patronage is not infrequently secured for new enterprises which can be made to appear "perfectly safe." The history of some of the numerous companies which have been floated in England for operating rubber concessions and plantations would make very interesting reading for the American investor. American rubber-planting enterprises are now much more extensive and on a much more secure footing than the English, but that they will entirely escape similar difficulties is scarcely to be expected.

Knowledge is lacking by which it is possible to judge with confidence the prospects of all rubber plantations, but there is absolutely no reason why any particular failure of planted rubber should be taken to mean that no cultivated rubber will be productive or that all rubber culture must be a failure. All plant cultures, tropical and temperate, have had their beginnings, so that the fact that rubber is a new agricultural product affords not the slightest reason why it may not be successful. Yet it can not be maintained that rubber is "as safe as any other crop," for the reason that there has been no opportunity to accumulate the experimental knowledge which would prevent failures.

REQUIREMENTS FOR SUCCESSFUL RUBBER PLANTATIONS.

It is hardly possible to set forth the difficulties and uncertainties which beset rubber culture without appearing to discourage the planter and the investor, though in reality there is no such intention, but only the desire that unnecessary mistakes and losses be avoided. There is no wish to warn anybody against rubber culture, either in the tropical islands of the United States or in other countries. The warning is against the idea that success and large profits are or can be assured without the caution and discrimination required for other branches of agriculture and other lines of investment.

Many factors must contribute to the success of a rubber-planting enterprise, while the lack of any one of them may turn profit into loss. At the risk of repetition, it may be well to enumerate some of the more important elements:

1. *Natural conditions of climate and soil must be favorable.*—This can best be inferred from the careful study of the wild rubber trees and other native vegetation. It is not safe to proceed under general ideas that Castilla will be productive everywhere in the Tropics, or that there are large regions or belts uniformly suitable for rubber. It is not safe to rely upon even the fact that neighboring plantations are productive, unless similarity of soil and topography has been ascertained.

2. *The plantation should be reasonably accessible.*—Although the bringing out of the rubber may not be difficult, the transportation of more bulky products and of the building materials and supplies, as well as the traveling expenses of the managers and laborers, will mean continuous charges with large totals. Some of the rubber estates of Mexico have already encountered unexpected difficulties and expenses in opening roads and buying steamboats.

3. *There must be an adequate and regular supply of labor.*—The cost of labor is also obviously important. Labor conditions may be very different in regions not far apart. The prospect in Mexico and Central America is an increasing scarcity of labor, higher wages, and larger expenses for quarters, supplies, and oversight necessary to keep laborers on the plantation. The conditions are entirely different from those of the United States, where the employer's responsibility so commonly ends with working hours and pay day. The cost of labor in Porto Rico does not compare unfavorably with that of many tropical districts of the continent, and the remaining inequality is rapidly disappearing.

4. *Local government must be stable and efficient.*—Unless located in regions controlled by stable and efficient governments the protection of rubber plantations against thieves may become a very large expense, to say nothing of the misfortune of general insecurity of life and property.

5. *The climate must be reasonably salubrious;* otherwise the difficulty and expense of labor and management may be greatly increased. Recent discoveries in tropical medicine, particularly the fact that malaria and yellow fever are communicated by mosquitoes, make it easier than ever before to secure protection against these diseases. The fact that rubber does not require continuous humidity also permits the extension of rubber culture in more salubrious localities.

6. *Plantation managers must be capable, efficient, and honest.*—Investors in rubber culture and other tropical enterprises are far more dependent upon the managers of their plantations than they are likely to appreciate without practical experience. That there is a great scarcity of competent and reliable managers of tropical plantations is well shown by the princely salaries now being paid by several of the

German coffee-plantation syndicates of Guatemala. And yet it is no uncommon occurrence for managers to resign such positions and go to planting for themselves. Great physical endurance, unusual executive ability, inflexible integrity of character, and extensive practical and local knowledge must be combined in a man who is able to handle successfully and honestly the complicated affairs of a large tropical plantation. He must be expert, or at least efficient, in everything from ditch digging to diplomacy, and when he is once well established and well acquainted with the country and with native customs, languages, and laws he is, as it were, master of the situation, and can make money many times as fast as any "new comer," no matter how capable. Many of the estimates of the cost of opening rubber plantations overlook the cost of management entirely, while others place it at a ridiculously insufficient figure. Some rubber plantations are being opened by men who have other remunerative interests which have enabled them to accumulate tropical experience and local knowledge, and who can be replaced only with much difficulty and much additional expense.

Investors in rubber plantations can not, as a rule, give personal attention to the points detailed above, but they have at least the responsibility of deciding whether the home officers of their companies have considered these and other obvious requirements for success. Without entering further into details, it may be said that, if many of the companies conduct their plantations as recklessly as they make advertising promises, the plantations and the promises must alike fail, or succeed only by the merest chance. It is, perhaps, unfair to impugn the honesty and intelligence of the officers of such companies, but it is certain that their advertising matter is being prepared by persons who know little about tropical agriculture in general or rubber culture in particular, or by those who carelessly or intentionally misrepresent the facts. The appeal is to the cupidity rather than to the good sense of the investor, though it is probably superfluous to warn those who have not yet learned that safe investments, bringing annual dividends of from 20 to 200 per cent do not go begging in the newspapers and magazines, while millions are available for anything which can assure returns at 5 per cent. It is a fact full of significance that during two decades and upward, in which many experiments were made by individuals and small companies, no large and well-advised interests invested in rubber culture. The importers and manufacturers of rubber in particular constitute a very intelligent and well-endowed financial community, which has from the first been keenly alive to the future of rubber production, and yet it is only within comparatively recent years that capital from this quarter has gone into rubber plantations, and even this has been applied in experimental quantities rather than in amounts indicative of established confidence in the prospects of rubber culture.

OPINION OF THE UNITED STATES CONSUL-GENERAL IN MEXICO.

As an antidote to the advertising claims of the numerous rubber companies, investors would do well to consider the report of Consul-General Barlow on "United States Enterprises in Mexico," published recently by the Bureau of Foreign Commerce of the Department of State.[a] Mr. Barlow finds that about $500,000,000 of American capital is invested in Mexico, about $350,000,000 of this being in railroads, $80,000,000 in mines, $28,000,000 in agriculture, and the remainder in manufactures, banks, and miscellaneous enterprises. The tenor of the discussion of investments in tropical agriculture may be judged from the following extracts:

> Many of them have given their authorized capitalization, running up into millions, as the amount of capital actually invested, when really the amount of capital paid in is a very small percentage of the authorized capitalization and the amount invested is still less, perhaps a few thousand dollars. The first cost of virgin land in the Tropics of Mexico is very small—say 50 cents to $1 per acre as a liberal average. Development work is expensive, and some of the older companies have no doubt spent considerable sums in improving their properties; but in a general way, the "monthly payment" companies have not invested much in Mexico, however much the small investors may have paid to the promoters for the privilege of holding stock in their companies.

It is pointed out that, while some of the agricultural companies are successful, "they are comparatively few." All persons are advised to visit Mexico before investing, and a definite warning is given that the promises of profits of 200 per cent and upward are fraudulent.

> The whole Isthmus of Tehuantepec, and possibly the entire tropical section of Mexico, could be bought by capitalists residing in this city, and if there were any sure 200 per cent investments to be made in that region they would certainly be taken up by persons on the ground who are thoroughly familiar with the conditions there. The speculative bubble will be pricked one of these days, and the small investors in the United States will have a lot of prettily engraved shares of stock and some more or less valuable experience to show for the money they have invested. I am in receipt of an average of ten or more letters each week from persons of small means in the United States who desire to invest in tropical agricultural companies operating or claiming to operate in Mexico, asking for information and advice concerning such companies and investments. One reply covers the whole ground. That is, first, that rubber culture in Mexico is as yet purely in the experimental stage, and no reliable statistics or information could be given concerning its probability of success. Promises of dividends by companies who propose to engage in the rubber-growing business are purely speculative and theoretical. * * * A small investment made by a school-teacher or minister or laboring man in the United States in a foreign enterprise blindly, may be well made; but in nine cases out of ten, the money could be invested to better advantage in the United States.

It should in fairness be repeated that the above quotations are made as an antidote rather than as representing an entirely satisfactory statement of the rubber situation. It would have been very difficult if not impossible for such a discussion as that of the consul-general

[a] Advance Sheets of Consular Reports, December 22, 1902.

to have given a correct impression of the percentage of rubber planting enterprises which are not reliable, even if he had been able to give the matter detailed investigation. No general condemnation of rubber planting either by individuals or by "monthly payment" companies is justified, but the certainty of success is not such that the investor can afford to be careless regarding the intelligence and reliability of those in whose hands he places his financial fate; and the consul-general will have performed an important service to the public if his statements are heeded, not as a general discouragement of rubber culture, but as a counsel of caution in making tropical investments.

CONCLUDING SUMMARY.

The culture of the Central American rubber tree has passed the experimental stage in the sense that the practicability of the agricultural production of rubber has been demonstrated, but on the other hand it has been ascertained that the tree may thrive where it will yield little or no rubber. Under favorable natural conditions the culture of *Castilla elastica* bids fair to become very profitable, but the experimental determination of the factors which influence the production of rubber has scarcely begun.

In southern Mexico and Central America the regions well adapted to the culture of Castilla are much more limited than has been supposed. The presence of wild Castilla trees is not a sufficient evidence that a locality is suited to commercial rubber culture.

Differences in the yield of rubber are not due merely to the existence of different species and varieties of Castilla, but are also controlled by external conditions.

The functions of the rubber milk in the economy of the plant are not well understood or agreed upon by botanists, but there are numerous reasons for holding that in Castilla and many other plants it aids in resisting drought.

A continuously humid climate is not necessary to the growth and productiveness of Castilla; the indications are rather that the quantity of milk and the percentage of rubber are both increased by an alternation of wet and dry seasons.

In its wild state Castilla does not flourish in the denser forests, but requires more open situations. It is confined to forest regions only by the perishability of its seeds.

Castilla thrives better when planted in the open than in the dense forest; even young seedlings are not injured by full exposure to the sun, providing that the ground does not become too dry.

The planting of Castilla under shade or in partially cleared forests is to be advised only on account of special conditions or as a means of saving labor and expense.

The loss of the leaves in the dry season may be explained as a protection against drought, and does not indicate conditions unfavorable to the tree or to the production of rubber.

The falling of the leaves of *Castilla elastica* in the dry season renders it unsuitable as a shade tree for coffee or cacao. In continuously humid localities where the leaves are retained shade trees are superfluous and the yield of rubber declines.

The desirable features of shade culture, the shading of the soil, and the encouragement of tall upright trunks, are to be secured by planting the rubber trees closer together rather than by the use of special shade trees. Planting closer than 10 feet, however, is of very doubtful expediency.

The percentage of rubber increases during the dry season and diminishes during the wet. The flow of milk is lessened in dry situations by inadequate water supply, but at the beginning of the rains such trees yield milk much more freely than those of continuously humid localities. The claim that more rubber is produced in the forest or by shaded trees seems to rest on tapping experiments made in the dry season.

Continuous humidity being unnecessary, the culture of Castilla may be undertaken in more salubrious regions than those to which rubber production has been thought to be confined; the experimental planting of Castilla in Porto Rico and the Philippines becomes advisable, but extensive planting in untried conditions is hazardous.

No satisfactory implement for the tapping of Castilla trees has come into use. Boring and suction devices are excluded by the fact that the milk is contained in fine vertical tubes in the bark, which must be cut to permit the milk to escape.

In British India it has been ascertained that the Para rubber tree may be repeatedly tapped on several successive or alternate days by renewing the wounds at the edges. The yield of milk increases for several tappings and the total is unexpectedly large. It is not yet known whether multiple tapping is practicable with Castilla, or whether this new plan may not give the Para rubber tree a distinct cultural advantage over Castilla.

The gathering of rubber from trees less than eight years old is not likely to be advantageous; the expense of collecting will be relatively large, and the quality of such rubber is inferior, owing to the large percentage of resin.

The rubber of Castilla is scarcely inferior to that of Hevea. The supposed inferiority is due to substances which can be removed from the milk by heat and by dilution with water.

DESCRIPTION OF PLATES.

PLATE I. Frontispiece. Planted Castilla trees about fourteen years old at La Zacualpa plantation, Soconusco, Chiapas, Mexico. The scarred trunks show that they have been tapped many times by the native method. The trees average about a foot in diameter and stand about twelve feet apart in the rows. They were planted in alternation with cacao, but this has mostly disappeared.

PLATE II. The original engraving of *Castilla elastica*, somewhat reduced. The staminate flowers are much longer than those shown in Plates V and VI and the fruits are in much looser and more spherical clusters than those of Plate VII.

PLATE III. Tip of branch of Castilla from Panzos, eastern Guatemala. Each leaf is covered when young by a large ribbed hairy scale. The young leaves appear much more hairy before they expand. (Natural size.)

PLATE IV. Staminate flowers and leaf base of Castilla from Panzos, eastern Guatemala. The scales are larger and less numerous than in Plate V, especially along the margins. The hairs of the branches are shorter and finer. (Natural size.)

PLATE V. Staminate flowers and tip of leafy branch of Castilla from La Zacualpa plantation, Chiapas, Mexico. (Natural size.)

PLATE VI. Pistillate and staminate flowers of Castilla from La Zacualpa, Chiapas, Mexico. Pistillate flowers at the left, the staminate at the right. The curved stigmas show in the middle of the pistillate clusters. At the side of each pistillate flower there may be one or two small staminate flowers quite different from those borne on branches which have staminate flowers only. (Natural size.)

PLATE VII. Clusters of ripe fruit, La Zacualpa, Chiapas, Mexico. The fruits are fleshy and of a rather reddish-orange color. (Natural size.)

PLATE VIII. Planted Castilla tree 18 months old at La Zacualpa, Chiapas, Mexico. Grown without shade.

PLATE IX. Castilla tree about 25 meters high, planted as a fence stake, Tapachula, Mexico. Said to be capable of yielding 25 pounds of rubber.

PLATE X. Young Castilla tree, showing self-pruned temporary branches, La Zacualpa, Chiapas, Mexico.

PLATE XI. Bases of self-pruned temporary branches of Castilla, La Zacualpa, Chiapas, Mexico. The one on the left shows an unusual character in being branched near the base. (Natural size.)

PLATE XII. Five large Castilla trees standing together, La Zacualpa, Chiapas, Mexico. These trees are a part of the plantation shown in the frontispiece, and are nearly as large as trees standing apart.

PLATE XIII. Yearling Castilla tree planted six months in the open, Panzos, Guatemala.

PLATE XIV. Yearling Castilla tree at Panzos, Guatemala, of the same age as that shown in Plate XIII, but standing in the shade and showing retarded growth.

PLATE XV. Thinly shaded Castilla plantation, trees 18 months old. La Zacualpa, Chiapas, Mexico.

PLATE XVI. Native method of tapping Castilla tree, La Zacualpa, Chiapas, Mexico.

PLATE XVII. Native method of coagulating latex. Fig. 1.—Spreading latex on Calathæa leaf, a leaf already coated shown at the right, lying in the sun to coagulate the rubber. Fig. 2.—Pressing the two coated leaves together, to unite the two sheets of rubber. Fig. 3.—Pulling the leaf away from the rubber. Fig. 4.—The finished sample of rubber, marked by the veins of the leaf.

PLATE XVIII. Fig. 1.—Sample of rubber coagulated in a bowl by juice of the moonvine. Fig. 2.—Branches bearing clusters of ripe fruit. Fig. 3.—Base of tree severely injured by careless tapping, but making new growth and showing the persistent vitality of the rubber trees of this region.

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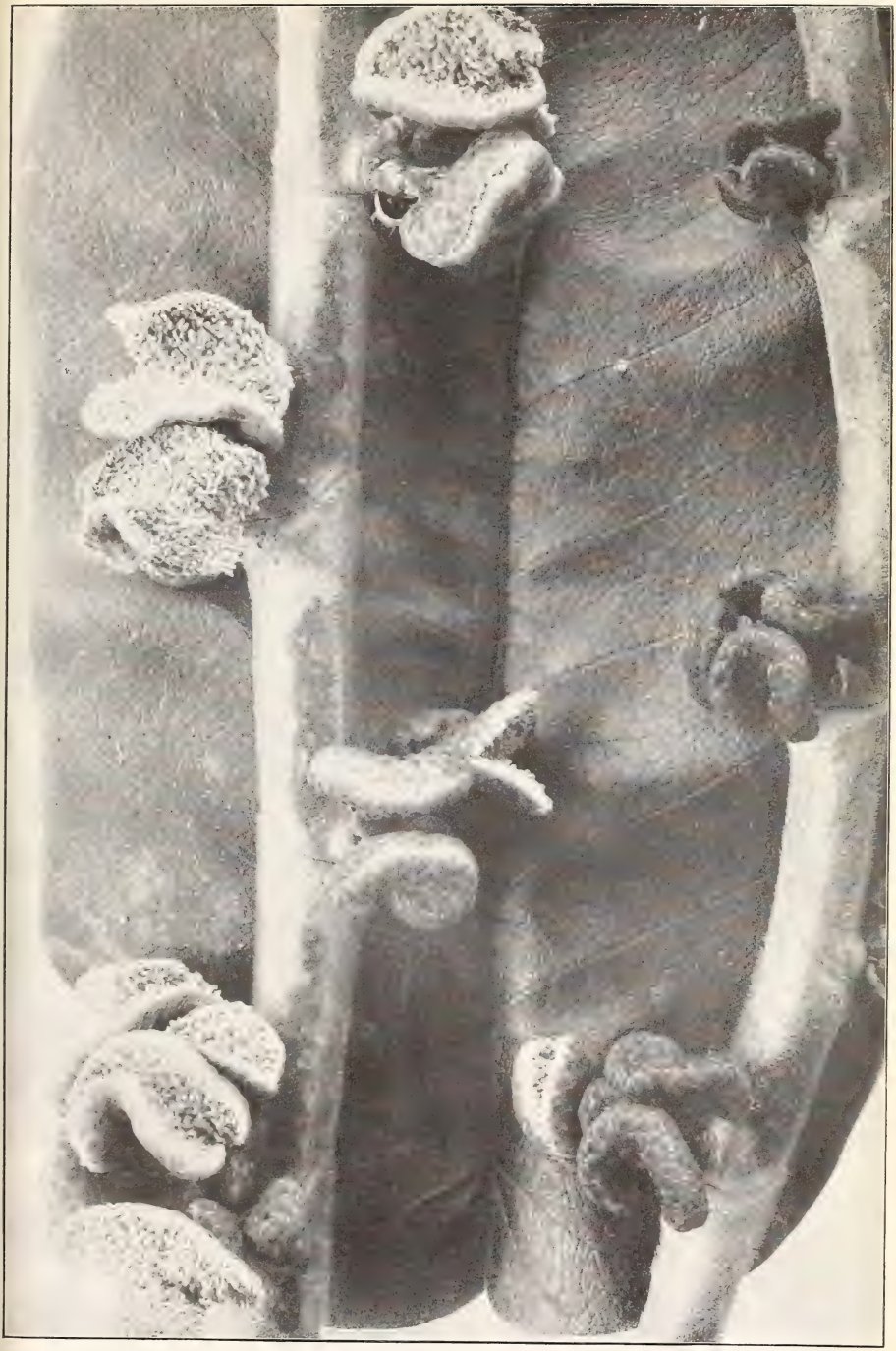
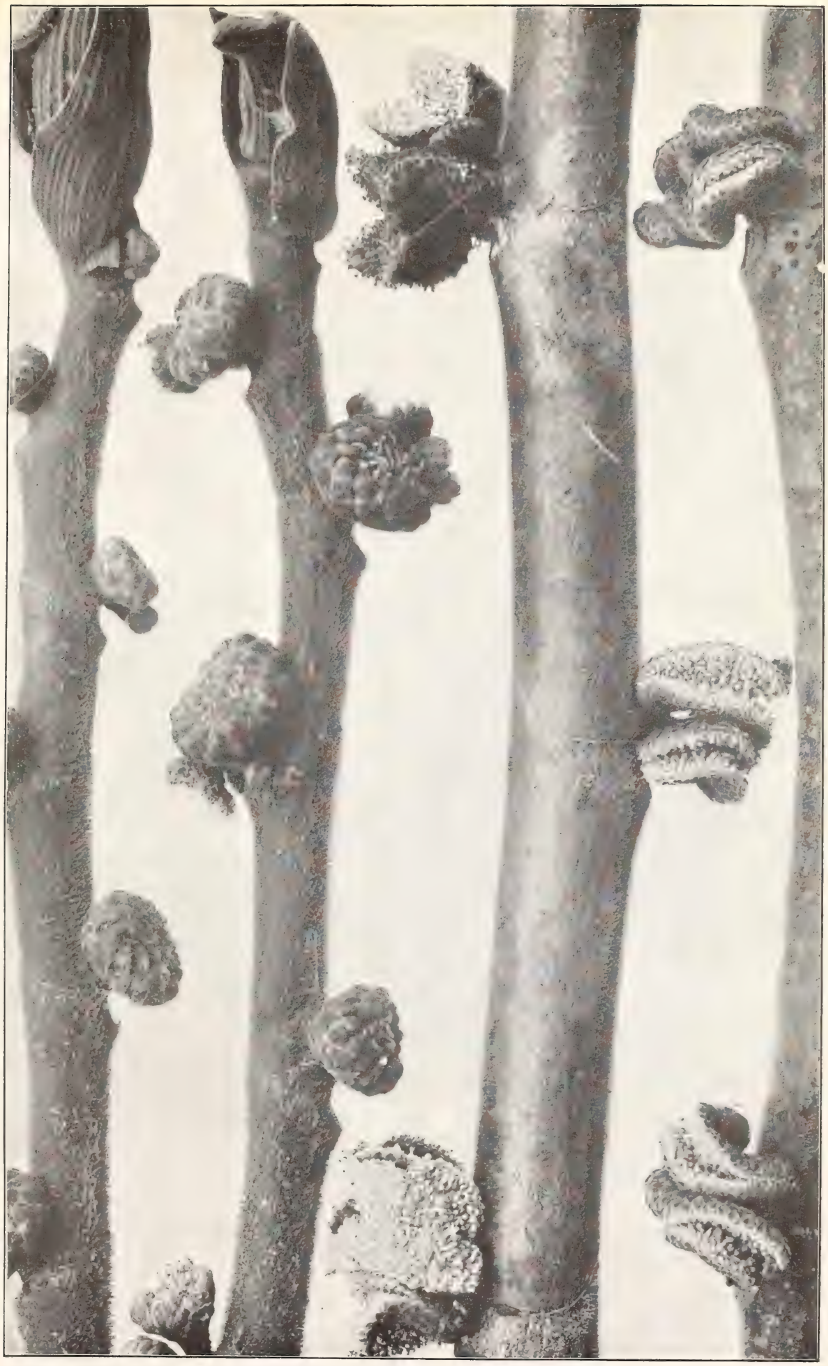
CERVANTES'S ORIGINAL ENGRAVING OF CASTILLA.

TIP OF BRANCH OF CASTILLA, EASTERN GUATEMALA (NATURAL SIZE).



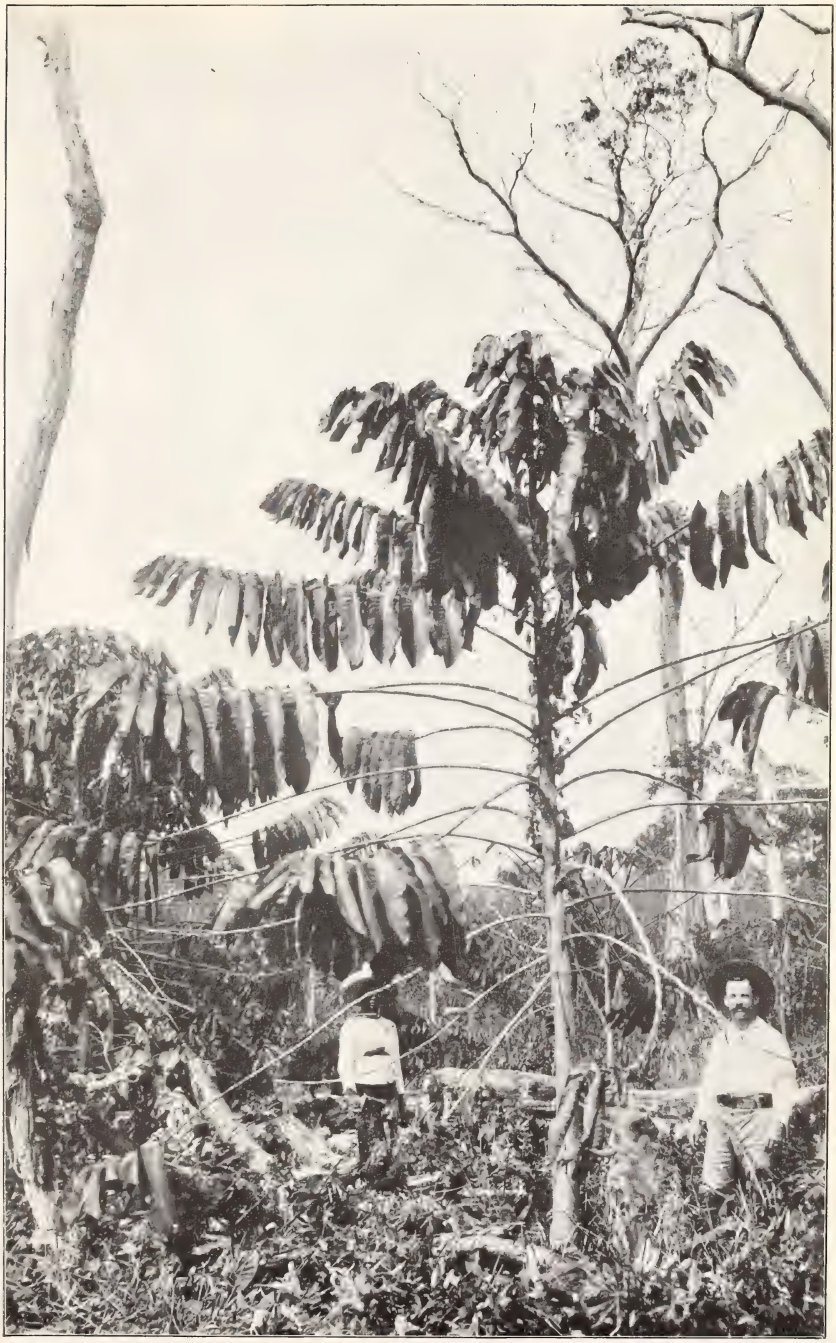
STAMINATE FLOWERS AND BASE OF LEAF OF CASTILLA, EASTERN GUATEMALA (NATURAL SIZE).

STAMINATE FLOWERS AND TIP OF LEAFY BRANCH OF CASTILLA, SOCONUSCO, MEXICO (NATURAL SIZE).



PISTILLATE AND STAMINATE FLOWERS OF CASTILLA, SOCONUSCO, MEXICO (NATURAL SIZE).

RIPE FRUIT OF CASTILLA, SOCONUSCO, MEXICO (NATURAL SIZE).



PLANTED CASTILLA TREE, 18 MONTHS OLD.

LARGE CASTILLA TREE GROWN FROM FENCE STAKE.

SELF-PRUNED BRANCHES OF CASTILLA.

BASES OF SELF-PRUNED TEMPORARY BRANCHES OF CASTILLA (NATURAL SIZE).

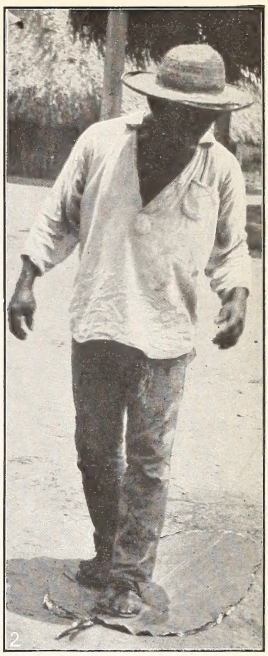
FIVE CASTILLA TREES STANDING TOGETHER, SOCONUSCO, MEXICO.

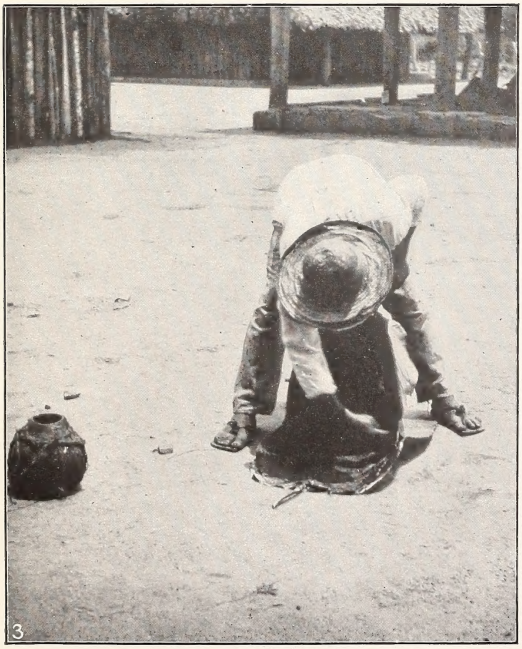
YEARLING CASTILLA TREE PLANTED IN THE OPEN, EASTERN GUATEMALA.

YEARLING CASTILLA TREE PLANTED IN SHADE, EASTERN GUATEMALA.

THINLY SHADED CASTILLA PLANTATION, 18 MONTHS OLD.

NATIVE METHOD OF TAPPING CASTILLA.





NATIVE METHOD OF COAGULATING LATEX.

1, Spreading latex on Calathæa leaf; 2, pressing two coated leaves together; 3, pulling the leaf from the rubber; 4, finished sample of rubber.

Bul. 49, Bureau of Plant Industry, U. S. Dept. of Agriculture.

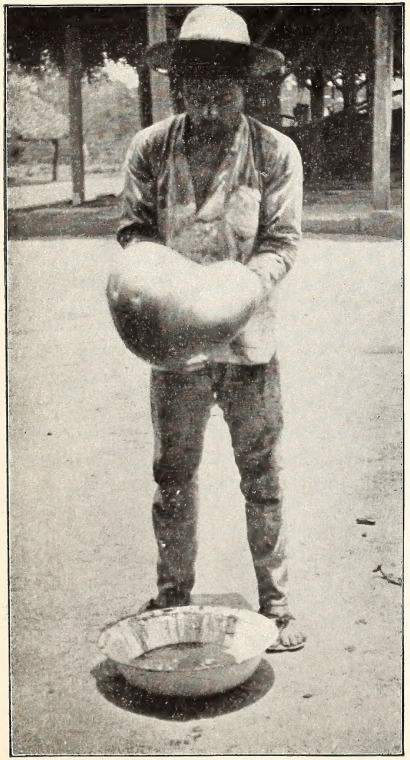


FIG. 1.—RUBBER COAGULATED BY JUICE OF MOON-VINE.

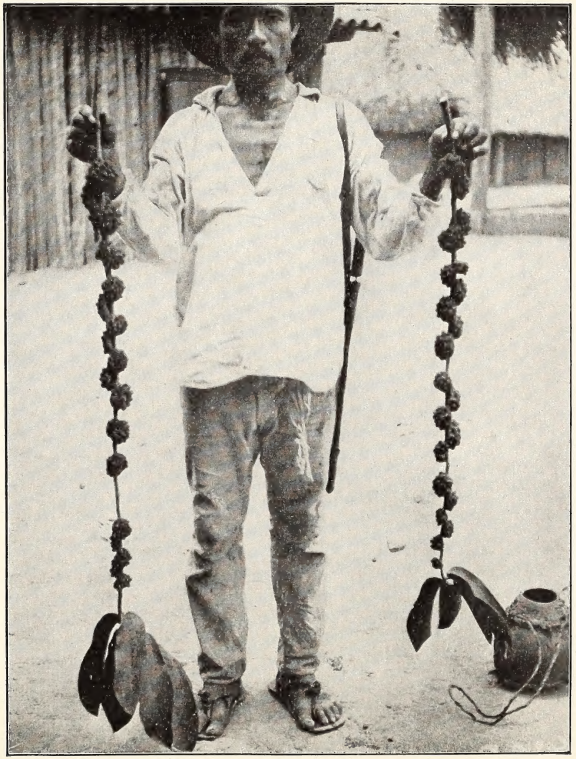


FIG. 2.—BRANCHES OF CASTILLA WITH RIPE FRUIT.

FIG. 3.—BASE OF TREE INJURED BY TAPPING.